Clinical Orthopaedics

ANTHONY F. DePALMA
Editor-in-Chief

With the Assistance of the
ASSOCIATE EDITORS
THE BOARD OF ADVISORY EDITORS
THE BOARD OF CORRESPONDING EDITORS

Number Thirteen
Spring, 1959

J. B. LIPPINCOTT COMPANY
Philadelphia and Montreal

Distributed in Great Britain by Pitman Medical Publishing Co., Limited, London

Library of Congress Catalog Card Number 53-7647

Clinical Orthopaedics is designed for the publication of original articles offering significant contributions to the advancement of surgical knowledge.

Original, typed manuscripts, not carbon copies, and illustrations should be forwarded prepaid to Dr. Anthony F. DePalma, 1025 Walnut Street, Philadelphia 7, Pa.

Manuscripts should be typed double spaced on one side of standard typewriter paper, leaving wide margins While every effort will be made to guard against loss, it is advised that authors retain copies of manuscripts submitted. All pages should be numbered. Dorland's *American Illustrated Medical Dictionary* (edition 22) and *Webster's New International Dictionary* (edition 2) should be used as standard references Scientific names for drugs should be used when possible. Copyright or trade names of drugs should be capitalized Units of measurement, e.g, dosage, should be expressed in the metric system. Temperature should be expressed in degrees centigrade. A contribution in a foreign language, when accepted, will be translated and published in English

Black-and-white illustrations will be reproduced free of charge, but the publisher reserves the right to establish a reasonable limit upon the number. Ordinarily, colored illustrations cannot be published except at the author's expense. Black-and-white photographs should be in the form of glossy prints. These should not be defaced in any way. Any changes desired in them should be marked on a tissue overlay. This should be done before it is pasted to the print, since it is important not to mar the print in any way Or any changes may be indicated on a separate sheet of paper. Line and wash drawings should be on white art board, with lettering in black India ink large enough to be readable after necessary reduction Large or bulky illustrations should be accompanied by smaller glossy reproductions of the same to facilitate their circulation among the members of the editorial board. Illustrations should be numbered, the tops indicated, and the author's name and the title of the article in brief should appear on the back. However, this should be done lightly, so as to leave no imprint on the face of the illustration. A separate typewritten sheet of legends for the illustrations should be supplied.

be

sc

Bibliographies should conform to the style of the *Quarterly Cumulative Index Medicus:*

If a book:

Author's name, title of book, edition if there is more than one, page numbers if it is wished to direct the reader to a specific section of the book, city in which publisher is located, publisher's name, year of publication of book, *in the order named.*

If an article in a journal:

Author's name, title of article, volume number, *inclusive page numbers, year of publication, in the order named.*

Manuscript may be submitted to us in the original language of the author. Now it is our policy to handle the translation of these articles by our office without cost to the contributor if the article is found to be acceptable for publication.

All manuscripts should be submitted with an extra carbon copy, including a short synopsis of approximately 200 to 250 words for translation into Interlingua.

Following are the general subjects of forthcoming issues of *Clinical Orthopaedics*

Recent Advances in Orthopaedic Surgery in Infancy and Childhood, Summer, 1959
The Hand, Part II, Fall, 1959
The Foot, Spring, 1960
Clinical Physiology and Pathology of Bone, Summer, 1960
Internal Derangement of the Knee Joint, Fall, 1960
Soft-Tissue Tumors, Spring, 1961

All contributors desiring to submit articles for consideration for publication on the topics listed above or in the general sections of this publication should submit them to the editor some months in advance of the date of the issue for which they are intended.

PRINTED IN THE UNITED STATES OF AMERICA

Contents

Section I

THE HAND: PART 1

Distributed in Great Britain by Pitman Medical Publishing Co., Limited, London

Library of Congress Catalog Card Number 53-7647

Clinical Orthopaedics is designed for the publication of original articles offering significant contributions to the advancement of surgical knowledge.

Original, typed manuscripts, not carbon copies, and illustrations should be forwarded prepaid to Dr. Anthony F. DePalma, 1025 Walnut Street, Philadelphia 7, Pa.

Manuscripts should be typed double spaced on one side of standard typewriter paper, leaving wide margins. While every effort will be made to guard against loss, it is advised that authors retain copies of manuscripts submitted. All pages should be numbered. Dorland's *American Illustrated Medical Dictionary* (edition 22) and *Webster's New International Dictionary* (edition 2) should be used as standard references. Scientific names for drugs should be used when possible. Copyright or trade names of drugs should be capitalized. Units of measurement, e.g., dosage, should be expressed in the metric system Temperature should be expressed in degrees centigrade. A contribution in a foreign language, when accepted, will be translated and published in English.

Black-and-white illustrations will be reproduced free of charge, but the publisher reserves the right *to establish a reasonable limit upon the number.* Ordinarily, colored illustrations cannot be published except at the author's expense. Black-and-white photographs should be in the form of glossy prints. These should not be defaced in any way. Any changes desired in them should be marked on a tissue overlay. This should be done before it is pasted to the print, since it is important not to mar the print in any way Or any changes may be indicated on a separate sheet of paper. Line and wash drawings should be on white art board, with lettering in black India ink large enough to be readable after necessary reduction. Large or bulky illustrations should be accompanied by smaller glossy reproductions of the same to facilitate their circulation among the members of the editorial board. Illustrations should be numbered, the tops indicated, and the author's name and the title of the article in brief should appear on the back. However, this should be done lightly, so as to leave no imprint on the face of the illustration.

[illegible]

betic order should appear at the end of the manu- [illegible] ; in the text. [illegible] style of the [illegible]

If a book:

Author's name, title of book, edition if there is more than one, page numbers if it is wished to direct the reader to a specific section of the book, city in which publisher is located, publisher's name, year of publication of book, *in the order named.*

If an article in a journal:

Author's name, title of article, volume number, *inclusive page numbers, year of publication, in the order named.*

Manuscript may be submitted to us in the original language of the author. Now it is our policy to handle the translation of these articles by our office without cost to the contributor if the article is found to be acceptable for publication.

All manuscripts should be submitted with an extra carbon copy, including a short synopsis of approximately 200 to 250 words for translation into Interlingua.

Following are the general subjects of forthcoming issues of *Clinical Orthopaedics:*

Recent Advances in Orthopaedic Surgery in Infancy and Childhood, Summer, 1959

The Hand, Part II, Fall, 1959

The Foot, Spring, 1960

Clinical Physiology and Pathology of Bone, Summer, [illegible]

Internal Derangement of the Knee Joint, Fall, 1960

Soft-Tissue Tumors, Spring, 1961

All contributors desiring to submit articles for consideration for publication on the topics listed above or in the general sections of this publication should submit them to the editor some months in advance of the date of the issue for which they are intended.

PRINTED IN THE UNITED STATES OF AMERICA

Contents

Section I

THE HAND: PART I

Distributed in Great Britain by Pitman Medical Publishing Co., Limited, London

Library of Congress Catalog Card Number 53-7647

Clinical Orthopaedics is designed for the publication of original articles offering significant contributions to the advancement of surgical knowledge.

Original, typed manuscripts, not carbon copies, and illustrations should be forwarded prepaid to Dr. Anthony F. DePalma, 1025 Walnut Street, Philadelphia 7, Pa.

Manuscripts should be typed double spaced on one side of standard typewriter paper, leaving wide margins. While every effort will be made to guard against loss, it is advised that authors retain copies of manuscripts submitted. All pages should be numbered. Dorland's *American Illustrated Medical Dictionary* (edition 22) and *Webster's New International Dictionary* (edition 2) should be used as standard references. Scientific names for drugs should be used when possible. Copyright or trade names of drugs should be capitalized. Units of measurement, e.g., dosage, should be expressed in the metric system. Temperature should be expressed in degrees centigrade. A contribution in a foreign language, when accepted, will be translated and published in English.

Black-and-white illustrations will be reproduced free of charge, but the publisher reserves the right to establish a reasonable limit upon the number. Ordinarily, colored illustrations cannot be published except at the author's expense. Black-and-white photographs should be in the form of glossy prints These should not be defaced in any way. Any changes desired in them should be marked on a tissue overlay. This should be done before it is pasted to the print, since it is important not to mar the print in any way. Or any changes may be indicated on a separate sheet of paper Line and wash drawings should be on white art board, with lettering in black India ink large enough to be readable after necessary reduction. Large or bulky illustrations should be accompanied by smaller glossy reproductions of the same to facilitate their circulation among the members of the editorial board Illustrations should be numbered, the tops indicated, and the author's name and the title of the article in brief should appear on the back. **However, this should be done lightly, so as to leave no imprint on the face of the illustration.** A separate typewritten sheet of legends for the illustrations should be supplied.

A bibliography of numbered references *in alphabetic order* should appear at the end of the manuscript with corresponding numbering in the text. Bibliographies should conform to the style of the *Quarterly Cumulative Index Medicus:*

If a book:

Author's name, title of book, edition if there is more than one, page numbers if it is wished to direct the reader to a specific section of the book, city in which publisher is located, publisher's name, year of publication of book, *in the order named.*

If an article in a journal:

Author's name, title of article, volume number, inclusive page numbers, year of publication, *in the order named.*

Manuscript may be submitted to us in the original language of the author. Now it is our policy to handle the translation of these articles by our office without cost to the contributor if the article is found to be acceptable for publication.

All manuscripts should be submitted with an extra carbon copy, including a short synopsis of approximately 200 to 250 words for translation into Interlingua.

Following are the general subjects of forthcoming issues of *Clinical Orthopaedics:*

Recent Advances in Orthopaedic Surgery in Infancy and Childhood, Summer, 1959

The Hand, Part II, Fall, 1959

The Foot, Spring, 1960

Clinical Physiology and Pathology of Bone, Summer, 1

Internal Derangement of the Knee Joint, Fall, 1960

Soft-Tissue Tumors, Spring, 1961

All contributors desiring to submit articles for consideration for publication on the topics listed above or in the general sections of this publication should submit them to the editor some months in advance of the date of the issue for which they are intended.

PRINTED IN THE UNITED STATES OF AMERICA

Contents

Section 1

THE HAND: PART I

Section II

GENERAL ORTHOPAEDICS

Section III

ITEMS

1

Sterling Bunnell (1882-1957)

August W. Spittler, Colonel, MC, U.S.A. (Retired), M.D.

Sterling Bunnell was born in San Francisco on June 17, 1882, the son of James Sterling Bunnell and Catherine Mapes Bunnell. He received his B. S. from the University of California in 1904 and his M. D. from the University of California Medical School in 1908. He interned at St. Luke's Hospital from 1908 to 1909. Early in his medical career he became deeply interested in experimental work in tendon and nerve sutures and grafts, and in the surgical problems of the extremities. This was the beginning of a lifetime work devoted to the restoration of the crippled human hand.

During World War I, Bunnell had a brief career as a medical officer, serving as Chief of Surgical Service, Base Hospital 47, with the rank of Captain, Medical Corps. His tour of duty ran from May, 1917, to March, 1919. For a time, he attended the Army's Neurological School, established in Philadelphia shortly after the war.

It was during his tour as an army officer in 1918 that he published his first article in *Surgery, Gynecology & Obstetrics,* "Repair of Tendons in the Fingers and Descriptions of Two New Instruments." His interest in hand surgery dated chiefly from this period, and was probably due to his recognition that it was a seriously neglected field of clinical investigation.

Incidentally, during this time he also became interested in aviation. After World War I he learned to pilot his own plane. Combining both interests, it was not unusual for Dr. Bunnell to fly all night to attend a conference and then fly back the next night to his practice in San Francisco. He served for a time as President of the National Aeronautical Society of the West. However, after years of flying, he crashed in 1926 and broke his hip. This ended his private flying career.

On his return to San Francisco after World War I, Bunnell engaged in general surgical practice. During this period he published a number of articles on a variety of subjects; among them, arterial sutures, cleft-palate repair in infants, a positive pressure apparatus for thoracotomy, esophagectomy, gallbladder surgery and, of course, hand surgery.

Continuing his military record in World War II, he served as Consultant in Hand Surgery to the Surgeon General, U. S. Army, and directly influenced the reconstruction of about 20,000 hands of our soldiers. Major General Norman T. Kirk, himself an eminent orthopaedic surgeon, recognized the importance of salvaging hands to restore men's usefulness and was the first to order the establishment of a Hand Service in each of the nine Army General Hospitals assigned as centers for plastic surgery. This was duplicated in overseas military hospitals wherever qualified medical officers were available to direct such services.

Dr. Bunnell entered upon his duties as Civilian Consultant on November 29, 1944, the very year that his monumental work on *Surgery of the Hand* was published. This book was adopted as an official text by the Army and was accepted immediately as the definitive work in its field. At this time he began the first of a series of eight tours

throughout the country. In the course of the succeeding 2½ years he visited nearly all the general hospitals in the United States as a civilian consultant. At each hospital he surveyed the procedures and the problems of hand surgery, gave active consultation in individual cases, and evaluated the qualifications of the medical officers assigned to the work. He conducted round-table discussions and clinics, operated on a number of patients to demonstrate his method, and conducted no less than 23 courses, of 3 or 4 days each, on the diagnosis and the treatment of hand lesions.

During these tours his impression of the treatment of hand injuries was not favorable. He found too many cases in which improper traction, splinting and skin-grafting resulted in less complete restoration of function than he considered possible. He directed much effort toward improving the quality of treatment by bringing together a number of orthopaedic surgeons, plastic surgeons and neurosurgeons to work on these injured hands in order to gain proper experience in their special problems.

He wrote:

> It is impossible to have three specialists work together or in series on a hand. The officers selected to do hand surgery should be able to do plastic, neurosurgical, and other orthopaedic surgery. This is forcefully necessary in hands due to the small size and to the fact that in this small space the three specialties are intimately interwoven. The only possible division would be to have the primary pedicle skin flap applied by a plastic specialist though this has its drawbacks and, of course, is not too difficult for anyone able to reconstruct hands *

He advocated concentration of complicated hand cases in a special service on a par with other major services in a hospital.

Dr. Bunnell's services to the Army did not end with the war So long as a considerable number of war injured remained in army hospitals, he continued his rounds. In 1946 he was awarded the Presidential Medal for Merit "in recognition of exceptionally meritorious conduct in the performance of outstanding services as Civilian Consultant, Surgical Consultants Division, Office of the Surgeon General." When his visits ceased in 1947, he accepted an appointment as a teaching consultant in hand surgery at Letterman Army Hospital, San Francisco. He also found time to serve as consultant to the Navy Hospital at Oakland.

After World War II, great interest was shown in hand surgery throughout the world. This resulted in 1946 in the organization of the American Society for Surgery of the Hand. Sterling Bunnell was the Society's first president. For the remainder of his life he continued to be its guiding force and was instrumental in encouraging the formation of "hand clubs" in Britain, Scandinavia and Japan and within the Latin-American Surgical Societies.

Perhaps his major contribution was in the surgical repair of tendon injuries of the hands and the fingers He advocated tendon grafts at a time when such surgery was fraught with the hazards of adhesions and infections. He emphasized constantly the importance of gentle nontraumatic handling of tissues and the use of fine, nonirritating suture material. His "pull-out sutures" were intended to remove the potential irritation of sutures from within the tendon sheaths. This concept he termed an "atraumatic technic," a phrase he used first in 1921. Dr. Bunnell was also a pioneer in advocating the use of nerve grafts for restoring sensation to the hands and the digits; he believed that in many badly damaged hands these grafts offered the only hope of restoration.

It was a pleasure to hear Dr. Bunnell analyze and solve a problem. His surgical technic depended upon a detailed and almost unbelievable knowledge of anatomy and skill in dissection He first approached a hand problem by trying to solve the anatomic fault, leaving the details to be logically developed per se. In his extensive monograph he described relatively little of the surgical technic of the procedures recommended; he

* J. Bone & Joint Surg 40 A 488, 1958

merely outlined the principle and left the experienced surgeon to work out the details by himself.

The second edition of *Surgery of the Hand*, published in 1948, and the third edition, in 1956, included the rapid development of hand surgery following World War II and the added stimulus of renewed experiences of the Korean conflict. *Surgery of the Hand* was translated into German and Spanish.

During Dr. Bunnell's lifetime, he published over 50 papers dealing with reconstructive and plastic surgery of the upper extremity. These included such subjects as the gig pull-out suture for tendons and nerve grafts for repair of facial nerves and extremity nerves. His development of "active splinting" of the hand and the fingers revolutionized the use of such splints and became standard equipment in their treatment. Among the specific procedures that he described were those for physiologic reconstruction of the thumb after total loss, intrinsic muscle contracture of the hand and tendon transfers for the upper extremity.

Dr. Bunnell enjoyed outdoor life, and all his life he retained an avid interest in natural history. Bird-hunting was probably his greatest outdoor love. He spent many enjoyable hours hunting and fishing. We are told by his friends that his knowledge of animal habits made him an unusually good hunter and fisherman and that to accompany him was to enjoy a postgraduate course in geology, forestry, botany and comparative anatomy. His study of animals was realistic, and from this came much of his detailed understanding of comparative anatomy and function. During the latter days of his life he turned to photographing wildlife, and his movies of the mountain sheep and the Alaskan brown bear were of professional quality.

Only a few men knew Dr. Bunnell intimately; he was reticent about discussing himself in any way. He was not argumentative, but he presented his own views with conviction. He taught by example, and to his many students he was a teacher of the highest rank. He held a jealous regard for the importance of his chosen field and would decline an invitation to lecture when he felt that the audience did not merit it.

Dr. Sterling Bunnell

His whole interest centered in his work, which he would discuss and demonstrate without hesitation. He never stopped creating. Each operation was a new experience; each patient was viewed as a problem to which he was willing to give his very special talents. He delighted in new ideas and was particularly pleased with each original contribution of his colleagues, provided that it passed his critical analysis.

Sterling Bunnell received many honors during his lifetime. He was a member of Sigma Xi. He was made a Chevalier of the Legion of Honor by France, and received the Ordem Nacional do Cruzeiro do Sul. He was an honorary member of the American Academy of Orthopaedic Surgeons, the American Orthopaedic Association, the

Western Orthopaedic Association, the California Society of Plastic Surgeons, the Sociedad Latino-Americana de Ortopédica y Traumatológica, an honorary fellow of the British Orthopaedic Association, and a corresponding member of the Societas Orthopaedica Scandinavica. He was also a member of the American Surgical Association, the American Association of Plastic Surgeons, the American Society of Plastic and Reconstructive Surgery, the American Association for the Surgery of Trauma, and the American Society for Surgery of the Hand. He was a Fellow of the American Occupational Therapy Association (1951-1953) and an emeritus member of the Hand Club of Great Britain. He was a licentiate of the American Boards of General, Plastic and Orthopaedic Surgery.

In San Francisco, Dr. Bunnell was a staff member of the Stanford University Hospital, the Children's Hospital and the St. Francis Memorial Hospital.

Dr. Bunnell died on August 29, 1957, at the age of 75. The Army's indebtedness to him may be summed up by an extract from the citation that accompanied his Medal for Merit:

> His tours of duty were made at heavy personal sacrifice and without regard to his own interests. The result was the attainment of functional results in surgery of the hand hitherto believed beyond attainment. Wounded soldiers who have been discharged from Army hospital with unimpaired hand functions, mutilated soldiers who have functional hands which once would have been useless, owe Dr. Bunnell a debt of gratitude, as do the Army surgeons who were taught by him and who will carry back into civilian practice the lessons which they learned from him and which they will apply for the benefit of all with similar injuries

Aside from his profound and complete knowledge of the hand, Dr. Bunnell's outstanding attribute was his enthusiasm and ability to teach. He could not tolerate stupidity; on the other hand, he was indefatigable in his desire to teach anyone his principles of hand surgery if he felt that they were prepared to receive his teaching or were qualified to understand his basic principles. He had an unusually brilliant mind, and at the age of 72 could still do more surgery on the hand in less time than many much younger men.

He went about his practice of medicine in a most systematic and orderly manner, making the most of every minute of the day and the night. His office was as well organized as his mind; it ran like a machine. He was a good artist and drew a picture of many hands that he examined, portraying its scars, neuromas, section tendons and deformed fractures. He was particularly adept at this and could do it quickly. He carried on clinical research continuously, and his records of his patients were masterpieces. In his office was a camera which he used every day during office hours to take countless photographs.

Socially, Dr. Bunnell was a charming person. If he undertook the responsibility of teaching anyone, he also enjoyed associating socially with that person. By the time he was 45 years old he was ready to retire, but, as with so many of his colleagues, the depression deflected him from that course. Although his great drive was devoted to the surgery of the hand, he never forgot that he was trained as a general surgeon. Until he died he continued to look after the total welfare of some of his very old patients. In 1945 he performed an abdominal perineal operation for carcinoma of the rectum, and as late as 1954 he nailed a fracture of the hip in the same patient.

Sterling Bunnell earned his niche in the developing history of American surgery by devoting his talents to a phase of disability and trauma which, until his work was appreciated, had failed to attract the widespread attention that it merited. As is often the case, once it gained the attention of the profession, its progress continued on its own momentum. A large percentage of the succeeding generations of the newly created group of hand surgeons were his pupils and

disciples. A damaged hand is a far greater handicap than its undramatic appearance suggests at first glance. Bunnell called the attention of his generation of surgeons to this fact and, to a large extent, told them what to do about it.

Sterling Bunnell published a large number of papers on hand surgery. Many were for teaching purposes and were responses to invitations. The bibliography is a selected one of his significant and original works.

BIBLIOGRAPHY

Bunnell, S.: Repair of tendons in the fingers and description of two new instruments, Surg., Gynec. & Obst. 26:103, 1918.

———: An essential in reconstructive surgery—atraumatic technique, Calif. State J. Med. 19:204, 1921.

———: Repair of tendons in the fingers, Surg., Gynec. & Obst. 35:88, 1922.

———: Reconstructive surgery of the hand, Surg., Gynec. & Obst. 39:259, 1924.

———: Surgery of nerves of the hand, Surg., Gynec. & Obst. 44:145, 1927.

———: Repair of nerves and tendons of the hand, J. Bone & Joint Surg. 10:1, 1928.

———: Contractures of the hand from infections and injuries, J. Bone & Joint Surg. 14: 27, 1932.

———: Surgery of intrinsic muscles of hand

—

Lippincott, Eds. 1-3, 1944, 1948, 1956.

———: Suggestions to improve the early treatment of hand injuries, Bull. U. S. Army M. Dept. (No. 88), pp. 78-82, 1945.

———: Active splinting of the hand, J. Bone & Joint Surg. 28:732, 1946.

———Restoring flexion to the paralytic elbow, J. Bone & Joint Surg. 33A:566, 1951.

———: Splinting the hand, Am. Acad. Orthop. Surgeons, Lect. 9:233, 1952.

———: Orthopaedic Appliances Atlas, vol. 1, Ann Arbor, Mich., Edwards, 1952.

———: Gig pull-out suture from tendons, J. Bone & Joint Surg. 36A:850, 1954.

Bunnell, S., and Boyes, J. H.: Nerve grafts, Am. J. Surg. 44:64, 1939.

Section I

THE HAND: PART 1

2

Comparative Anthropology of Man's Hand

Charles W. Goff, M.D.*

Fig. 1. Hand of Man in gestures of Attention, Halt or Peace, used by many peoples the world round.

It is not clear whether the word *hand* is derived from the old Gothic *handus*, the Danish *haand* or the Germanic *Hand.* Language origins are evasive. However, the anatomic term *manus* clearly comes from the Latin *manipulus;* hence, *man* "is he who has *hands* to *manipulate.*" In this sense hands become instruments defined by Aristotle as "antecedent to, or productive of, all other instruments; *organs of investigation instead of locomotion.*"

EVOLUTION AND DEVELOPMENT

Actually, the hand of man is a universal tool, used with great skill. We like to think of it as something very special, but in truth the human hand has not specialized. It is quite a primitive structure. While it represents a precise apparatus, with 24 muscle

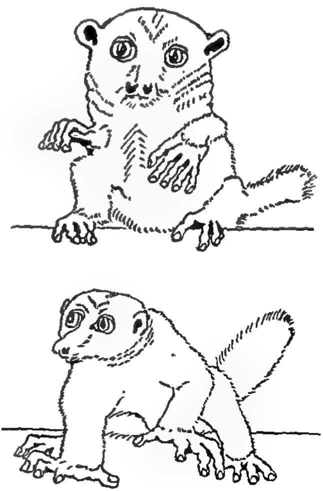


Fig. 2. Two species of tarsiers, lowest form of primate, with classic small brain,

man Note the opposing thumbs and longer clutching fingers, designed for manipulating while sitting on the haunches.

* Hartford, Conn.

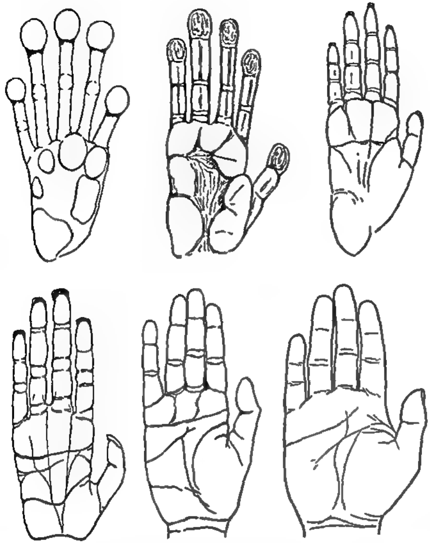


FIG. 3. Palmar surfaces of primate hands. (*Top, left,* tarsier; *center,* lemur; *right,* Rhesus monkey.) (*Bottom, left,* chimpanzee; *center & right,* varieties of Man.)

groups rich in motor and sensory nerves, it has retained the ancient five-finger pattern common to all vertebrates With time, reflexes of the human hand have been greatly suppressed, whereas sensory responses have been increased In the truest sense, man's hand is an organ of sensation as well as of

FIG. 4. (*Above*) Hand of Chimpanzee (*Right*) Manner of placing weight on knuckles during locomotion Note hyperextension of digits and no extension at wrists. (Riesen and Kinder The Postural Development of Infant Chimpanzees, New Haven, Yale)

manipulation. Without these capacities man's brain might have remained undeveloped; hence the retention by a pair of hands of a primitive pattern, size and shape, with diminished reflexes and increased sensitivities, enabled man to "feel" himself above all other animals.

It is unsafe to compare our hand with a fin or a paw, because man's evolutionary development is not clear prior to the appearance of a small four-legged ape in East Africa called Proconsul. This small ape was a quadruped; it used its anterior extremities both for weight-bearing and for manipulations while sitting. It was a good climber and brachiator. The thumb apposed all four fingers with ease and power. Complete fossil specimens attest to this by the presence of a saddle-shaped os multangular major, articulating with the pollex or the first metacarpus.* No other anthropoid except man apparently is prepared to perform this movement so well. Proconsul probably placed the palm flat while weight-bearing, exactly as man does when he tries to "walk on all fours." The great apes—the orangutan, the chimpanzee and the gorilla—bear weight on their knuckles, have thick skin on their fingers, and are unable to dorsiflex their wrists when in this position. They need this stability for locomotion, using their arms as crutches. While their arms are proportionately longer than man's, their thumbs are shorter, and metacarpals are longer. Man's thumb is more powerful than that of any of the great apes. I have tested my strength of grasp against that of an adult chimpanzee, whose body weight was 135 pounds at 25 years of age, and my grasp was greater. If motivated by fear, the chimpanzee might have excelled.

SENSORY ORGAN

Although grasping is the major function of the hand, it is at the same time one of man's primary sensory organs, as I have indicated. This tactile quality provides sensory experience that may be grouped into four general categories, according to Alpenfels. The first consists of "surface sensations," stimulation generated by touching tangible objects. The second might be called "space-filling," stimulation generated by pulling the hand through a liquid. "Space-like sensations," a third category, is related to the touch of distinctively shaped objects, felt through a heavy material. Finally, there are "penetrable surface sensations." For example, that capacity used by a physician as he palpates a part of the body in order to locate through the outer layer of tissues some structure within the deeper regions.

FIG. 5. The hand as an organ of erotic sensation. From an oil painting of the 16th century by Banzoni. (In a gallery in Italy)

Vibratory sensations, as perceived by the hand, are useful for teaching the deaf to speak. By placing one hand on the larynx of a speaker and the other hand on his own

* Fossil specimens were examined recently by the author through the courtesy of J. R. Napier, Department of Anatomy, Royal Free Hospital, School of Medicine, in London, England

larynx, the deaf may learn the vibration patterns of speech sounds. When the patterns "heard" by his left and right hands are identical, the student has succeeded in imitating the sound. Helen Keller utilizes vibratory phenomena when she "hears" music by placing her hand on the piano.

THE BEGINNING OF PALMISTRY

The old Stagirite philosopher of the Greeks has recorded that "the destiny of man is traced in the lines of his hand," a belief that still survives in some places. Aristotle, quoted by Pliny, taught that broken lines in the hand indicated a short life. Goethe regularly had his palm read by wandering Andalusian gypsies.

An old writer has summarized the formerly popular beliefs:

> A great, thick hand signifies one not only strong but stout; a little slender hand, one not only weak but timorous; a long hand and long fingers betoken a man not only apt for mechanical artifice, but liberally ingenious; but those short, on the contrary, note a fool and fit for nothing; an hard brawny hand signes dull and rude; a soft hand, witty but effeminate; an hairy hand, luxurious, the often clasping and folding of the hands note covetous; and their much moving in speech, loquacious; an ambidexter is noted for ireful, crafty, injurious; short and
>
> ward, niggardly; long nailes and crooked, signes one brutish, ravenous, unchaste; very short

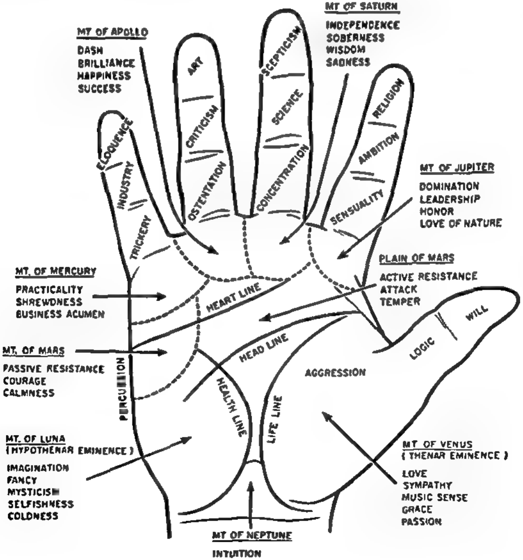


FIG. 6 The palm and its markings for the palmist of 100 years ago

nailes, pale and sharp, show him false, subtile, beguiling; and so round nailes, libidinous; but nailes broad, plain, thin, white, and reddish, are the tokens of a very good wit.*

Hand symbolism long has held man's fancy. Many early writers attest to a close connection between the form of the hand and the psychological disposition of the person to whom it belonged. Even Sir Charles Bell, who needs no introduction to medical readers, appears to have tolerated a touch of belief in chirognomy. This "science" concentrated on the shape and the lines of the palm and elevations of the hand as guides to character.

Although palmistry has survived, no longer is it given any scientific credence. Crossing lines, stars, long or short lines, zigzag lines, and a variety no less than 70 in number of such conformations, one for each year of man's life, concerned the early palmists. Today the physician approaches hand studies with confidence, based on true correlations, not signs of the zodiac.

THE DIAGNOSTIC HAND

An editorial in the Journal of the American Medical Association (vol. 154) notes that

> the human hand is a unique organ from which an extraordinary amount of clinical information may be derived

particularly in cardiovascular diseases. The hand's size, especially the fisted hand, is said to resemble the cardiac silhouette: if large, the heart is large; if small, the heart usually is small. Osler's nodes, small tender red nodules, located in the pads of the fingers, in the thenar or the hypothenar eminences, are said to indicate a subacute bacterial endocarditis. If pallor of the palm is observed, the diagnosis is clear. Cyanosis and clubbing of the fingers have been associated with congenital heart disease, although usually not appearing until the child is 2 years of age. If present, the clinician should look

FIG. 7. Johannes Hartlieb, physician, A.D. 1470, presenting his *Book on the Hand* to the Duchess Anna of Bavaria. Reproduced from his first edition. (Ciba Symposia, The Hand, No. 4, July, 1942)

for accompanying malformations elsewhere in the body.

Hyperthyroidism and neurocirculatory asthenia may be indicated by warm, moist palms in the former and cold, damp palms in the latter. Both may have an accompanying tremor. Tremors are of many varieties. No one could confuse those of Parkinson with an alcoholic or a tabetic.

Raynaud's syndrome primarily involves the fingers; congestive heart failure, the whole hand.

Temperature changes of the skin of the hands are dramatic indicators of many disorders. Impending causalgia in fractures and other trauma of the upper extremities may signal its likeliness by sudden swelling, heat and great pain of the hand. The shoulder-arm-hand syndrome is well known to the orthopaedist with its pattern of sensory changes, geographically distributed. Hysterical "opera glove" anesthesia carries its own story. A youth's age may be determined by roentgenographic characteristics of the bones of the hand and the wrist with far greater accuracy in a developmental sense than the date on a birth certificate.

Multiple traits of disorders showing hand manifestations could be further extended.

* Burdick, L. D.: The Hand, Oxford, N. Y., The Irving Co., *1905*

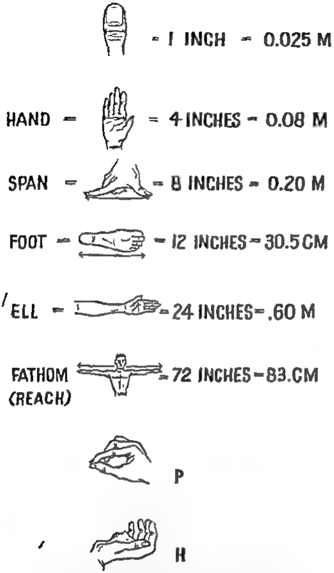


FIG 8 The hand in measurements of Man (P) A pinch, used to measure gold dust or salt for the sauce (H) A handful, common measure the world round.

These few characteristic diseases and injuries are of common knowledge wherein the hand is of great assistance to the physician. Is it any wonder that Hartlieb, a physician, published a monograph on palmistry for his medical confreres of 1470. The supernatural has always entered into "predictional fields," not alone the province of the doctor of medicine. We may smile at our ancestors' beliefs in chiromancy We prefer to call it "diagnosis by inspection," because today we have valid, correlated studies of the hand in a host of disorders to fortify our concepts We have removed a good deal of the witchcraft of 1470.

STRANGE HAND BELIEFS AND CUSTOMS

The birth of a child lacking hands, or with malformations of them, according to the omen tablets of the ancient Assyrians, indicated that serious calamities would befall the people. At Belshazzar's feast the king was filled with terror because

> in the same hour came forth fingers of a man's hand, and wrote over against the candlestick upon the plaster of the wall of the king's palace: and the king saw the part of the hand that wrote.*

The day of the week on which the nails were pared was of great significance, and still is for some. The Arabians religiously observed Friday as the proper day, and so did Edgar Allan Poe. According to the Laws of Manu, sacred objects must be passed with the right hand toward them. Ambapali once invited Buddha and his followers to her home. She was always careful to keep him on her right hand when she passed by him. In the Vedic marriage ceremony the bridegroom takes the bride's right hand and leads her from left to right around the household fire. This is still done during the Russian wedding ceremony. Egyptian deities carried the amulet of life in the left hand. Lao-tse said:

> The superior man makes the left hand, the weak side, the place of honor, but he who goes forth to use weapons of war, honors the right, the strong hand.†

Apollo was always placed on the right hand of Jove by Roman poets. A very ancient belief, that good or ill luck attended the first sight of a new moon, has survived to the present time. If seen over the right shoulder, it brings good fortune; if over the left, it is unlucky.

* Daniel 5:5.

† Conway, M D : Sacred Anthology, p. 53, New York, Holt, 1902.

MATHEMATICS AND MEASURES

Someone has said that the fingers are "the arithmetic of every child and of primitive man." An Australian aborigine has no single name for any number above two; he used the same word to express numbers above that and held up his fingers to signify how many he meant. The Demaras have none above three and use their fingers above that. The word of the Tasmanians which expresses more than two means plenty. Sir Thomas Browne* said:

> Antiquity expressed numbers by the fingers of either hand; on the left they accounted their digits and articulate numbers unto an hundred; on the right hand hundreds and thousands.

The very word *digit*, which signifies one of the ten symbols by which numbers are expressed, is literally one of the terminal divisions of a finger or a toe, and the use of the fingers in counting and computing has caused the same term to be used to designate figures. I = the numeral for one, the pictorial expression for the uplifted finger of the primitive counter; V = the symbol for five, the open hand with fingers and thumb extended; X = ten, two hands placed together, with fingers and thumbs extended. The Roman foot, although divided into twelfths, was divided likewise, after the manner of the Greeks, into four handbreadths and sixteen fingerbreadths. The finger, the thumb, the hand, the palm, the forearm, the foot, the extended arms and the extended legs have all played a fundamental part in determining the standard measures of the civilized world The ell is a measurement of the forearm plus hand. The hand still measures the height of horses. The fingers of the seamstress are her constant and "ready to hand" measuring devices.

When primitive man had counted the fingers and the toes and reached the limit of the whole man, he made a notch in a stick and began again The metric system, of course, is in *tens*. The ancient Maya used a vigesimal system, counting all digits of hands and feet—*twenties*.

The tithe, a tenth, one "finger's worth," must also be reckoned among the institutions of great antiquity that have grown out of the early use of the hands in arithmetic computations.

* Vulgar Errors, p. 4, London, Bohn, 1852.

TRIAL BY HAND

In the past the hand has been a prominent factor in formulas and ceremonies for detecting the guilt or proving the innocence of persons suspected of crime. For example, all the widows of a dead man are suspected in some districts of Africa of killing their husbands by witchcraft, and their guilt or innocence is determined by subjecting them to a prescribed ordeal. The night following the death they are taken before an assembly of chiefs and people into a clear space, where there is a fire burning. A chicken is tied to the right hand of each of the women, who are then taken before the fire. If, at the sight of the fire, a fowl attached to one of the widows fails to cluck, that woman is adjudged guilty.

King James I wrote in his book on demonology:*

> In a secret Murther, if the dead Carkasse be at any time thereafter handled by the Murtherer, it will gush out with blood, as if the Blood were crying to Heaven for revenge of the Murtherer.

In New England, in 1646, a mother who was suspected of murdering her child was compelled to touch its body—"the blood came freely into the child's face and she confessed." These words can be found in the court transcript.

When these ordeals revealed criminals, the punishment was sometimes inflicted upon their hands. The Hindu thief lost his hand according to the Code of Manu.

* Daemonologie (1597). Contains also "Newes from Scotland declaring the Damnable Life and Death of Doctor Fian, a notable Sorcerer who was burned at Edenbrough in January last (1591)."

FIG 9. Stone-Age Man Restoration diorama, life size, of an Aurignacian cave near Gargas, France, about 30,000 years ago. Artist is blowing powdered red ocher round his outstretched fingers to make outline on wall, a religious technic. Note the large number of amputated fingers amongst the palm prints. (The Photographic Section, Chicago Natural History Museum)

TRANSMITTING POWER AND PRAYER

The hand has been a medium for the transmission of power, both actual and symbolic. The laying on of hands is an accompaniment of or a supplement to many other rites; it belongs to the ordinances of baptism, consecration and confirmation. The hand of God, laid upon the prophets of Israel, was the source of their inspiration. Jesus took up little children in his arms and "put his hands upon them and blessed them." To raise the hand was used frequently by itself in the sense of offering a prayer, and so by a natural transition it came to be employed as a synonym for prayer or "to utter a prayer." The clergy today use the sign to bless *with a silent prayer.*

The ancient Chaldeans sealed covenants with uplifted hands. The Persians, too, lifted their hands to the sun in adoration. The Hebrews, like the Babylonians, accompanied their prayers with the lifting of hands. Lifting the hand accompanied ceremonies of divination among the ancient Greeks. The sacred symbol of the uplifted hand has been found over the doorway of temples all over the world. Sometimes it is the *hand of Fatima,* daughter of Mohammed, or it may be the *Corn Goddess of the Maya*

THE HAND LIFTED IN OATH-TAKING

Oath is an Anglo-Saxon-Teutonic word; it is an appeal to God for the truth of what is affirmed and is essentially a religious rite,

invoking God's vengeance upon him who violates it. Abram lifted his hand unto God that he would have none of the spoils of King Bera. Laying the hand on and kissing the sacred book is a customary form of administering an oath in England and in Ireland. In Scotland the affirmant holds up his right hand and repeats the oath after the official who administers it. An affirmation, with the right hand upraised, is a legal form in the United States. The Mohammedan lays his right hand flat on the Koran and then touches it with his forehead.

FIG. 10. Hands in designs of early cultures. (*Left*) Early American-Indian designs; also the hand of Fatima, used wherever Moslem cultures are found. (*Center*) Mayan hieroglyph. (*Right*) Mandan-Indian hand stamp.

THE WASHING OF HANDS

When Pilate found no evil that merited death in Jesus, and the multitude insisted upon it, he took water and washed his hands to free himself of guilt. "I will wash mine hands in innocency." To wash hands before an act of worship was a ceremony handed down by Greek and Roman rituals through the ages. Catholic ritual follows ancient sacrificial usage in the priest's ceremonial washing of hands before mass.

MAN'S HANDS SPEAK

Montaigne* thought

> that there is not a motion of the hands that does not speak in an intelligible language . . . a public language that everyone understands.

Pantomimists wore masks so that it was chiefly by their hands and fingers that they expressed themselves. By the manual sign-language of the deaf, words of orators are interpreted rapidly and intelligibly to those who cannot hear them.

Among all nations there are more or less movements of the hands and the fingers that come to have a conventional meaning. The use of the hand in friendly greeting is mentioned in the literature of the oldest nations. "I kiss your hand" is a form of salutation of education and refinement in some of the old countries of Europe. The expression points to a time when the hand actually was kissed

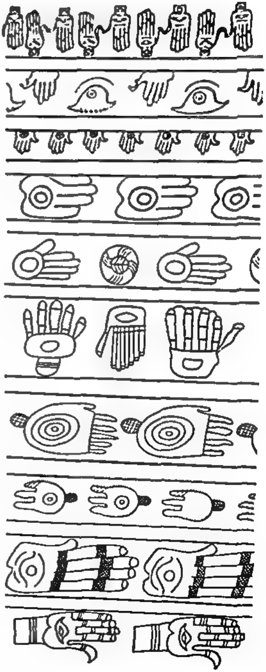


FIG 11. Hands in pottery borders for burial bowls. (*Southeastern Indians Art and Industries,* editor Emma L. Fundaburk, Luverne, Ala.)

* The Nature of Things (translated by J. S. Watson), p. 1045, London, Bell, 1901.

as a part of the ceremony of an introduction. Latin gentlemen still are prone to kiss a lady's hand.

The practice of shaking hands, which prevails so extensively in modern times, is believed to have originated in the habit of adversaries' grasping the weapon hand during a truce as a precaution against treachery. The warrior grasped the weapon hand of an enemy to prevent mischief and extended his own weapon hand to a friend to show that he was not himself on the defensive.

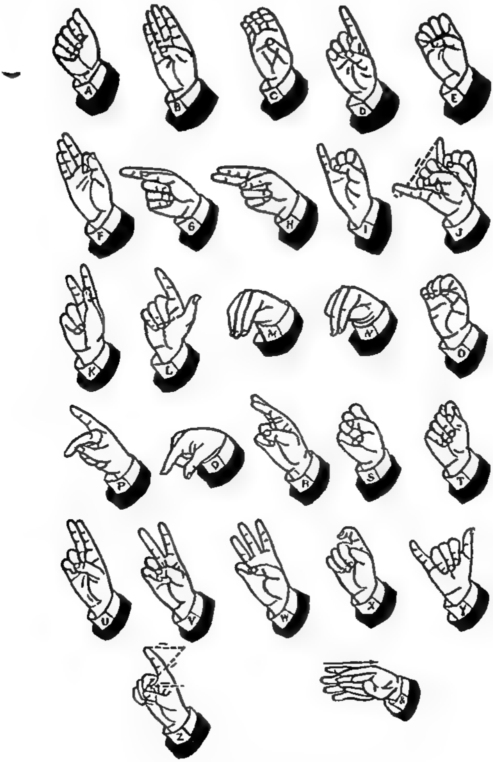


FIG 12 Hand alphabet of the deaf.

The custom of shaking hands on the completion of a deal is alluded to by early English writers and is still common practice among many peoples.

In various ways, symbolism of the hands in ceremonial rites and customs has come to indicate social class and caste. For example, among the Balinese it is a mark of social distinction to wear long nails, but only the priest may wear them on both hands.

Many-handedness was common with the giants and the heroes of the Greeks and the Teutons. Many hands and arms are common features of Hindu representations of deities. In each of her ten arms the goddess Durga bears a weapon with which she protects the ten points and slays the enemies of her worshipers. Siva, the destroyer with a thousand names, who mastered both Life and Death, was provided with four, eight or ten hands.

Feelings, beliefs and sentiments with which the hand is associated in the varied experiences of life have been crystallized into epigram, maxim and proverb, and pervade the literature of the world:

> Don't measure a man's sincerity by the vigor of his handshake.
>
> The hand that gives gathers.

It is said of a man who is clumsy and awkward that "his fingers are all thumbs." Other sayings are:

> There is no better sign of a brave man than a hard hand.
>
> Every honest miller has a thumb of gold.
>
> The hand that rocks the cradle rules the world.
>
> You win, hands down.

HANDEDNESS—SUPERSTITION OR SCIENTIFIC PHENOMENON

Has man a preferred hand? As the reader has noted, many folk tales apparently indicate an acknowledged preference. Dexterous = right and righteous, left = sinister and sinful, to this day. Preference for the right hand came about because the left hand was needed to cover the left chest with a battle shield, the side supposedly containing the vital heart organ. Selection by warfare over the years brought about right-handedness. Amazonian warriors cut off their right breasts the more easily to draw their long bows with their right hands. Of course, these examples are strictly legendary. However, credence has been given to brain, hemispheric dominance for nearly 200 years. Many have devised tests, supposedly indicating an eye dominance similar to handedness. Early anthropologists declared that the gross difference between man and the anthropoid apes, relative to their brain construction, was indicated by asymmetric frontal lobes in man, symmetric in apes. This difference in size was said to have been brought about by handedness. Thus, the left frontal lobe was greater in right-handed people. We now suspect that this is not a scientifically valid concept.

In 1884, Sir Francis Galton tested visitors to his booth at the Health Exhibit of the World's Fair by strength of grip tests. He considered the stronger hand the preferred, or dominant, and constructed a percentage table for races of mankind. Here the anthropologist was led astray. Strength is not a valid test of dominance. Usually, a violinist has a strong left hand, stronger than a truck driver's. Surgeons and pianists have strong hands with ambidexterity a common characteristic. Nevertheless, there seems to be a slight relationship between eye and hand dominance, such as throwing, threading a needle, writing, kicking, and striking a match. Heredity influences and environmental training may alter this selectivity. Twins usually are similar. Random samples of adult populations indicate that 88 per cent are right handed, while 12 per cent are left handed. Great apes have no preferred hand, as in the case of an infant. There are said to be 28 per cent left-handed major-league pitchers. What does this indicate?

It has been said that left-handedness was

FIG 13. Tattooing details on the hand of a Marquesan queen. (*Shapiro, H. L.: Natural History* 67:213)

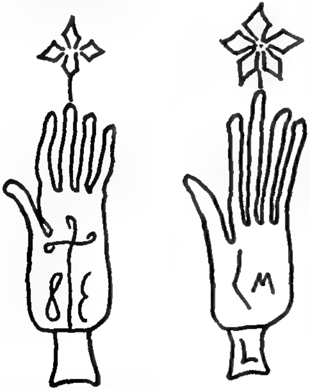


FIG 14 Stamps with initials used as signatures in the 16th century, a time when most administrators and civil servants could not write

quite common among biblical Jews. Tribe of Benjamin had 700 skillec handed slingmen. Our modern cult *frankly right handed. This biased en* ment may account for the greater nı of right-handed people.

Benjamin Franklin wrote a pleasan morous and ingenious letter to a concerning handedness in which he pe fied the left hand as follows:

> *The left hand complained of being suffe* grow up without instruction. The left har had no master to teach it writing, drawin suitable accomplishments; that on the co the left hand is left totally without exercis for the sympathy of the right hand

So far as we know, Franklin was handed.

THE HAND FOR PERSONAL IDENTIFICATION

Human hands have been used in va *cultures as a means of positive identifica* In ancient China, fingerprints were us sign or to autograph paintings. They doubly valuable as "signatures" because *cannot be altered or forged. Their intr* patterns of whorls, circular and folded lc and arches differ from finger to finger from individual to individual. As the pe *grows, his individual fingerprint pattern* crease in size but do not change in geom proportions. In 1882, Bertillon, a yc French anthropologist, began to develop famous system for identification of crimi by a physical description based upon ele anthropometric measurements of the h and the face, together with deformities impressions of lines and markings of fingertips. The Bertillon International S tem of Fingerprints has been used for p sonal identification the world round e since, although considerably extended character.

THE HAND IN ART

As a powerful symbol of magic and indicator of mental attitudes, the hand

ways has played a major role in the creative arts of all periods and all peoples. In Egyptian and Assyrian art, hands usually were treated schematically. The Greeks and the Romans strove to achieve a precise correspondence with reality. The hands, next to the face, are drawn by artists of the Renaissance with particular care. The great masters spent endless hours drawing hands in all manner of positions, expressing multiformed emotions, always in magnificent detail. Their hands usually told as much or more than

FIG. 15. Dürer, a 16th-century artist, used great care in the hands of his subjects. *These speak for the painter in his scene of* "The Young Jesus with the Doctors." (In the Galleria Barberini, Rome)

FIG. 16. The creation scene of Adam, from the ceiling of the Sistine Chapel, by Michelangelo, A.D. 1510. (*Left*) Hand of Adam. (*Right*) Hand of God.

their subjects' faces. Early American portrait painters frequently painted the face and the hands with exquisite care, then indifferently smeared on the clothing. Sculptors took special interest in hands. Rodin frequently left it to his subjects' hands to tell the tale. The hand studies of Dürer are classics of the painter's art. The hands of many artists are their signatures, so to speak.

The greatest symbolic use of hands by a master is represented in the Creation of Adam Scene, by Michelangelo, painted on the ceiling of the Sistine Chapel. Adam is pictured reclining in a state of lethargy, and God, with his right hand, is about to touch Adam's left hand for the transmission of life. Here are hands in the best tradition, the hand of God and the hand of man.

And so it must have been an inspired moment, when a great friend of mine portrayed his wife's right hand on the dedication page of his greatest book. How fitting a tribute!

BIBLIOGRAPHY

Adamson, C. L.: Handedness: result of hereditary and environmental factors in cerebral dominance, Texas J. Sci. 6:211-216, 1954.

Alpenfels, E. J.: The anthropology and social significance of the human hand, Artificial Limbs 2:4-21, 1955.

Bell, Sir Charles: The Hand, London, George Bell & Sons, 1877.

Burdick, L. D.: The Hand, Oxford, N. Y., The Irving Company, 1905.

Ciba Symposia: The Hand, vol. 4, pp. 1294-1327, 1942.

Della Porta, Giovan Battista (Napolitano): Della Fisonomia Dell'Huomo Padua, 1613.

DeLys, Claudia: A Treasury of Superstitions, New York, Philosophical Library, Inc., 1957.

Editorial: The hand and cardiovascular disease, J.A.M.A. 154:508, 1954.

Fletcher, M. J., and Leonard, F.: The principles of artificial hand design, Artificial Limbs 2:78-94, 1955.

Goff, C. W.: Evolutionary status and comparative morphology of man, Am. Acad. Orthop. Surgeons, Lect. 6:212-218, 1949.

———: Man's hand, its injuries and values, Amicus Curiae 1:5-13, 1956.

Hill, W. C. O.: Man's Ancestry (A Primer of Human Phylogeny), Springfield, Ill., Thomas, 1953.

Jones, F. W.: The Principles of Anatomy As Seen in the Hand, Ed. 2, Baltimore, Williams & Wilkins, 1942.

Merrell, D. J.: Dominance of eye and hand, Human Biology 29:314-329, 1957.

Müller, W.: Die angeborenen Fehlbildungen der menschlichen Hand, Leipzig, Thieme, 1937.

Murphy, E. F.: Engineering—hope of the handless, Artificial Limbs 2:1-3, 1955.

Napier, J. R.: Form and function of the carpometacarpal joint of the thumb, J. Anat. 89:362-366, 1955.

———: The prehensile movements of the human hand, J. Bone & Joint Surg 38B:902-913, 1956.

Shapiro, H. L.: The Hand. Les Iles Marquises. Natural History 67:213-216, 1958.

Taylor, C. L., and Schwarz, R. J.: The anatomy and mechanics of the human hand, Artificial Limbs 2:22-35, 1955.

Anthropologia Comparative del Mano Human

Summario in Interlingua

Le mano del homine es describite per Aristotele como "un organo de investigation." Su evolution es considerate como limitate. In essentia illo ha remanite un structura primitive con reducite reflexos e augmentate sensibilitates. Isto ha resultate in le grande dimensiones e capacitates cerebral del homine. *Proconsule*, un micre simia de Est-Africa, es probabilemente le plus ancian ancestre del homine [illegible] possede un simile (ben que non identic) pollice oppositive. Le mano del homine ha multe valores esoteric, exprimite in designos de arte, in le religion, le linguage de signales, [illegible] chiromantia. Iste ultime es un studio occulte sin base scientific. Pro le [illegible] mano es un

organo de interesse diagnostic, per exemplo in morbo de Raynaud e in disordines cardiovascular e nervose. Es discutite superstitiones e costumes relative al mano, e etiam legendas, unitates de mesura, e significationes pantomime e symbolic. Dexterismo e sinistrismo es naturalmente plus o minus equal, ben que le cultura reinfortia generalmente le dexterismo. Le identification del homine per le impression de su digitos o su palma es un systema ancian. Le artistas ha, depost longe tempores, usate le mano del homine pro exprimer su emotiones. Le mano es un instrumento universal. Le homine ha usate lo con dexteritate pro fabricar omne le altere instrumentos que existe in nostre mundo.

their subjects' faces. Early American portrait painters frequently painted the face and the hands with exquisite care, then indifferently smeared on the clothing. Sculptors took special interest in hands. Rodin frequently left it to his subjects' hands to tell the tale. The hand studies of Dürer are classics of the painter's art. The hands of many artists are their signatures, so to speak.

The greatest symbolic use of hands by a master is represented in the Creation of Adam Scene, by Michelangelo, painted on the ceiling of the Sistine Chapel. Adam is pictured reclining in a state of lethargy, and God, with his right hand, is about to touch Adam's left hand for the transmission of life. Here are hands in the best tradition, the hand of God and the hand of man.

And so it must have been an inspired moment, when a great friend of mine portrayed his wife's right hand on the dedication page of his greatest book. How fitting a tribute!

BIBLIOGRAPHY

Adamson, C. L.: Handedness: result of hereditary and environmental factors in cerebral dominance, Texas J. Sci. 6:211-216, 1954.

Alpenfels, E. J.: The anthropology and social significance of the human hand, Artificial Limbs 2:4-21, 1955.

Bell, Sir Charles: The Hand, London, George Bell & Sons, 1877.

Burdick, L. D.: The Hand, Oxford, N. Y., The Irving Company, 1905.

Ciba Symposia: The Hand, vol. 4, pp. 1294-1327, 1942.

Della Porta, Giovan Battista (Napolitano): Della Fisonomia Dell'Huomo. Padua, 1613.

DeLys, Claudia: A Treasury of Superstitions, New York, Philosophical Library, Inc., 1957.

Editorial: The hand and cardiovascular disease, J A.M.A. 154:508, 1954.

Fletcher, M. J., and Leonard, F.: The principles of artificial hand design, Artificial Limbs 2:78-94, 1955.

Goff, C. W.: Evolutionary status and comparative morphology of man, Am. Acad. Orthop. Surgeons, Lect. 6:212-218, 1949.

———: Man's hand, its injuries and values, Amicus Curiae 1:5-13, 1956.

Hill, W. C. O.: Man's Ancestry (A Primer of Human Phylogeny), Springfield, Ill, Thomas, 1953.

Jones, F. W.: The Principles of Anatomy As Seen in the Hand, Ed. 2, Baltimore, Williams & Wilkins, 1942.

Merrell, D. J.: Dominance of eye and hand, Human Biology 29:314-329, 1957.

Müller, W.: Die angeborenen Fehlbildungen der menschlichen Hand, Leipzig, Thieme, 1937.

Murphy, E. F.: Engineering—hope of the handless, Artificial Limbs 2:1-3, 1955.

Napier, J. R.: Form and function of the carpometacarpal joint of the thumb, J. Anat. 89: 362-366, 1955.

———: The prehensile movements of the human hand, J. Bone & Joint Surg. 38B:902-913, 1956

Shapiro, H. L : The Hand. Les Iles Marquises. Natural History 67:213-216, 1958.

Taylor, C. L., and Schwarz, R. J.: The anatomy and mechanics of the human hand, Artificial Limbs 2:22-35, 1955.

Anthropologia Comparative del Mano Human

Summario in Interlingua

Le mano del homine es describite per Aristotele como "un organo de investigation." Su evolution es considerate como limitate. In essentia illo ha remanite un structura primitive con reducite reflexos e augmentate sensibilitates. Isto ha resultate in le grande dimensiones e capacitates cerebral del homine *Proconsule,* un micre simia de Est-Africa, es probabilemente le plus ancian ancestre del homine e possede un simile (ben que non identic) pollice oppositive. Le mano del homine ha multe valores esoteric, exprimite in designos de arte, in le religion, le linguage de signales, e chiromantia. Iste ultime es un studio occulte sin base scientific. Pro le medico, le mano es un

organo de interesse diagnostic, per exemplo in morbo de Raynaud e in disordines cardiovascular e nervose. Es discutite superstitiones e costumes relative al mano, e etiam legendas, unitates de mesura, e significationes pantomime e symbolic. Dexterismo e sinistrismo es naturalmente plus o minus equal, ben que le cultura reinfortia generalmente le dexterismo. Le identification del homine per le impression de su digitos e su palma es un systema ancian. Le artistas ha, depost longe tempores, usate le mano del homine pro exprimer su emotiones. Le mano es un instrumento universal. Le homine ha usate lo con dexteritate pro fabricar omne le altere instrumentos que existe in nostre mundo.

3

Anatomy, Injuries and Treatment of the Extensor Apparatus of the Hand and the Digits

EMANUEL B. KAPLAN, M.D.*

The extensor apparatus of the hand consists of a complex that includes the extensor tendons to the digits. The extensor apparatus of each digit is a combination of the extensor digitorum communis tendon and the terminal tendons of the interossei and the lumbrical muscles integrated into a unit by transverse and oblique fibers. Common characteristics of structure are found over all the digits, but there are also differences over the index and the little fingers and, especially, the thumb.

It is essential to know the details of structures and action of the different elements entering into the structure of the dorsal apparatus.

CERTAIN ASPECTS OF NORMAL ANATOMY

One important factor characterizes the anatomic pattern of the extensor apparatus over the fingers; it is an intimate interconnection of the extensor apparatus, the ligamentous structures of the joints and the flexor retinaculae.

THE LONG EXTENSORS OF THE FINGERS AND THE DORSAL APPARATUS OF THE HAND

The extensor apparatus of the dorsum of the hand moves by action of the long extensors that originate in different areas of the forearm. The extensor pollicis longus and the extensor pollicis brevis, the extensor indicis proprius and the extensor digiti minimi proprius, each has a comparatively independent origin. However, the extensor digitorum communis, which is independent of the muscles mentioned, binds the action of the index, the middle, the ring and the little fingers into a common unit. The proper extensors of the index and the little fingers permit almost complete independent motion of these two fingers. In contrast, the middle finger and, especially, the ring finger are so bound by the common origin of the extensor

* [illegible] ians [illegible] pital [illegible]

FIG 1. The common mass of the extensor digitorum when stimulated with an electric current produces extension of 4 digits which is not increased by section of the juncturae tendinum Extension of the index and the fifth fingers is possible when the flexors of the ring and the middle fingers are flexing these 2 fingers. Extension of the ring finger at the metacarpophalangeal joint when the little and the middle fingers are flexed, but the index is extended, is practically impossible even under strong electric stimulation although the juncturae are completely divided. (*Illustration on facing page*)

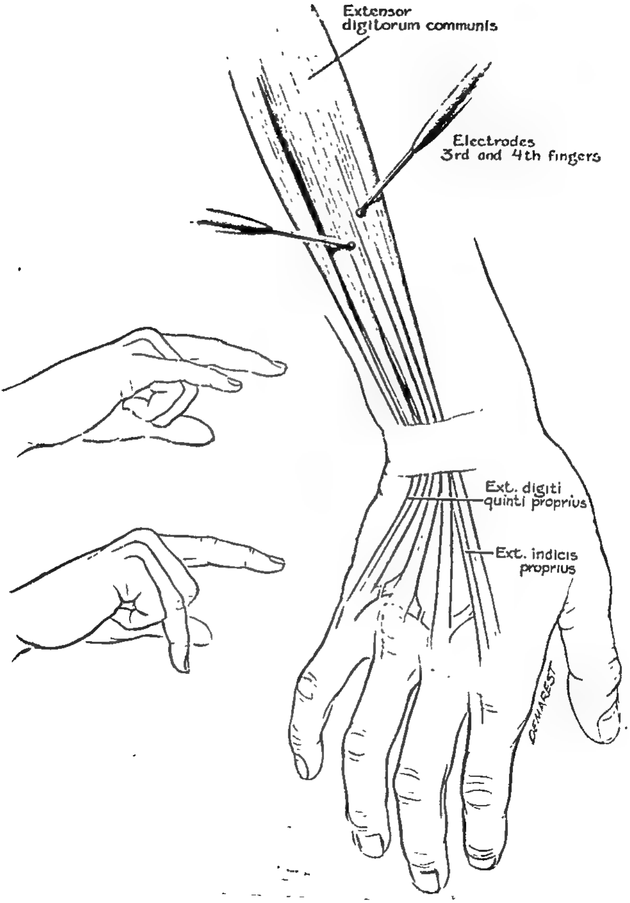


FIGURE 1 *(Caption on facing page)*

digitorum communis that independent motion of these two fingers is not possible. Generally, the limitations of extension of the ring finger, while the others are flexed, do not interfere with the usual activities of the hand. However, there are instances in which *limitations of extension of the ring finger* become very annoying. It is sometimes observed in musicians, especially pianists, and causes them great mental distress.

The origins of the extensor pollicis longus and the extensor indicis proprius are the most independent. The origin of the extensor digiti minimi proprius is less independent. It starts from the posterior aspect of the radial epicondyle of the humerus in common with the extensor digitorum communis but posterior to it; however, it separates from the common extensor very rapidly and runs an independent course.

The extensor digitorum communis originates from the anterior and the inferior aspect of the radial epicondyle of the humerus and from an area on the lateral aspect of the ulna just posterior to the insertion of the orbicular ligament of the proximal radio-ulnar joint, the antebrachial fascia and the intermuscular septae. The fleshy fibers to the four digits descend to the distal third of the forearm, where the separate tendons appear. The very limited independence of each of the four digits is conditioned by the slight separation of fleshy fibers of each digit in the common mass. (Fig. 1)

The extensor apparatus over the dorsum of the hand consists of intertendinous divergent fibers that run parallel to the tendons and connect the individual tendons in a fan-like manner from the wrist to the metacarpophalangeal joints. These connections vary considerably; very rarely they form an almost continuous intertendinous sheet uniting all the tendons into one structure. Generally, the tendons are separated and are running to the mid-point of each metacarpophalangeal joint. The extensors proprii to the index and the little fingers are located on the ulnar side of the corresponding tendon of the extensor communis. The variations in the disposition and the number of tendons are numerous. In rare instances, dorsal to the extensor digitorum communis tendons, a few small muscular bodies may be found. They represent a homologue of the *extensor brevis of the foot* and *originate* from the carpal bones or from the metacarpals and insert into the tendons of the long extensors near the metacarpophalangeal joint of the middle or other fingers. These fibers are known as extensor digitorum brevis manus. The existence of this muscle, if unsuspected, may contribute to an erroneous diagnosis of a dorsal ganglion or a tumor of the dorsum, or even a hematoma after injury.

The tendons of the extensor digitorum communis are connected by short oblique slips running in a distal direction, usually from the medius to the index and the ring fingers, and from the ring to the little finger. They are found in the distal part of the dorsum, proximal to the metacarpophalangeal joints, and are known as juncturae tendinum (the recent *Nomina Anatomica Parisiensia* calls them connexus intertendineus). The juncturae were considered to be responsible for restriction of individual extension of the ring and other fingers. Operative divisions of these junctions did not correct the disability because restrictions of extension of the middle and the ring fingers are due mostly to the interconnection in the fleshy mass of the extensor digitorum communis.

The extensor tendons are covered by a thin sheath of fascia that is continuous with the most superficial fascia of the dorsal carpal ligament and extends over all the tendons of the dorsum.

Dorsal Apparatus of the Fingers, Excluding the Thumb

The dorsal apparatus over the dorsum of the fingers results from convergence toward the metacarpophalangeal and the interphalangeal joints of the long extensor and the

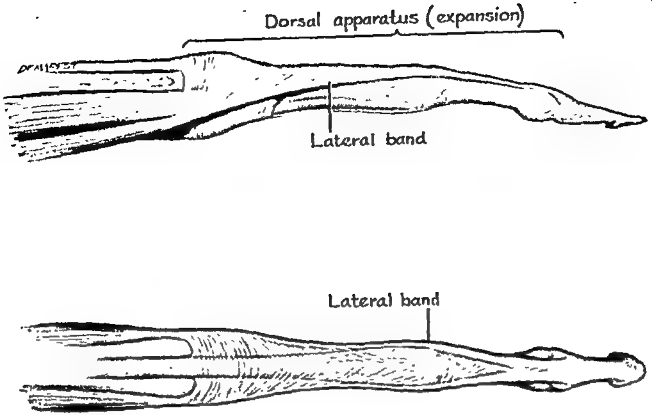


FIG. 2. The extensor apparatus, or expansion, of any finger, except the thumb, shows that the structure is an inseparable unit divided into separate elements for purposes of description. Actually, it is continuous and intimately interconnected. The central portion of the extensor tendon cannot be separated from the lateral peripheral bands, or lateral bands, but by section. The oblique and the transverse fibers over the metacarpophalangeal, the proximal and the distal joints are as much a part of the apparatus as the lateral bands are.

intrinsic tendons. Its structure and function were investigated by a number of anatomists and clinicians (Landsmeer, Baumann and others). The author's personal investigations added some information on the embryology and the function of the fingers in problems of injuries and congenital deformities.

The tendon of the extensor communis, combining with other elements over the area of the metacarpophalangeal joint, is integrated into a fibrous expansion crossed by transverse and oblique fibers running around the metacarpophalangeal joint. The oblique fibers of the expansion run on each side of the joint. They are directed volarly and distally, and become fixed at several points: (1) the lateral sides of the base of the proximal phalanx; (2) the lateral collateral ligaments; and further distally to the deep transverse ligament at the volar fibrocartilaginous plate of the metacarpophalangeal joint.

The expansion thus anchors securely the extensor tendon to the metacarpophalangeal joint, balancing the tendon constantly over the long axis of the joint. The obliquity of the fibers of the expansion permits the tendon to move distally and proximally for normal extension and flexion. (Fig. 2)

The volar under side of the extensor tendon is also attached by long fibers either to the dorsum of the capsule of the metacarpophalangeal joint or to the dorsal base of the proximal phalanx. These fibers are completely relaxed when this joint is flexed. When the extensor tendon is in complete extension, these fibers are in full tension and

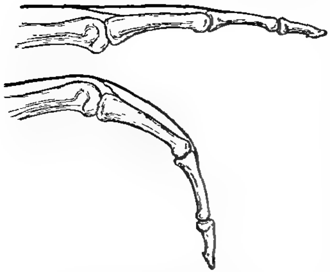


FIG. 3. Diagrammatic illustration of the relation of the extensor tendon to the capsule of the metacarpophalangeal joint in flexion and extension.

pull the proximal phalanx into hyperextension. (Fig. 3)

Experimental division of the expansion on either side of the metacarpophalangeal joint in the cadaver produces slipping of the extensor tendon from the divided side when the joint is flexed. It produces deviation of the proximal phalanx to the same side. The same phenomenon is observed when a disruption of the expansion occurs on one side in traumatic or pathologic instances and frequently is observed in arthritis, causing deviation of the fingers.

The extensor apparatus over the metacarpophalangeal joint is intimately connected with the terminal tendons of the interossei and the lumbrical muscles. This becomes more apparent slightly distal to the metacarpophalangeal joint. The extensor tendon itself breaks up in the depth of the expansion into a group of divergent fibers running from the metacarpophalangeal joint distally to the base of the middle phalanx. Most of these fibers run in the long axial line of the proximal phalanx and end over the entire width of the base of the middle phalanx; the other peripheral fibers run to the sides of the dorsal expansion, which is represented by a thickened free edge on each side of the proximal phalanx. The free edge of the expansion is known as the lateral band and runs on each side of the proximal phalanx from the insertion of the apparatus into the lateral base of the proximal phalanx along the sides of the proximal phalanx to the proximal interphalangeal joint. (Fig. 2)

The lateral bands at the lateral bases of the proximal phalanx are intimately connected with the tendon of the corresponding interosseous muscle. The tendon of the interosseous muscle has a double insertion: one part of the tendon is anchored to the lateral tubercle of the base of the proximal phalanx, where it shares its insertion with the expansion of the extensor apparatus; the other part of the interosseous tendon joins the free edge, or lateral band, of the apparatus.

A few millimeters more distally, the tendon of the lumbrical muscle also joins the lateral bands of the radial side. Halfway distally over the proximal phalanx, the dorsal expansion consists of two lateral bands and a central portion. The central portion, corresponding to the continuation of the tendon of the extensor digitorum communis, runs over the entire width of the dorsum of the capsule of the proximal interphalangeal joint from one collateral ligament to the other. This portion adheres intimately to the capsule and inserts into a ridge just above the articular line of the dorsal base of the middle phalanx from side to side and into a small tubercle just distal to the ridge. The lateral bands continue on each side of the proximal interphalangeal joint but dorsal to the axis of flexion and extension of this joint. These bands reach the dorsum of the middle phalanx. Each band runs outside the dorsal tubercle of the middle phalanx and joins the other band just distal to the dorsal tubercle to form a wide unit for insertion into the dorsum of the distal phalanx.

The wide terminal band adheres to the dorsal part of the capsule and inserts into a

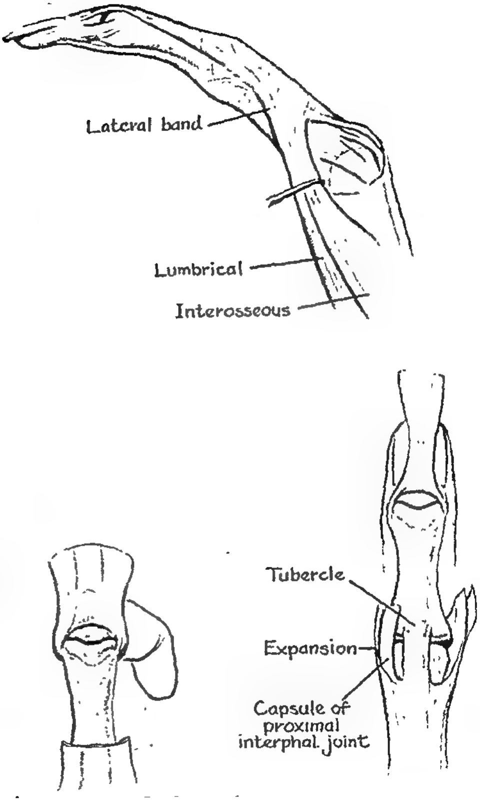


FIG. 4. (*Top*) Relation of the extensor apparatus at the metacarpophalangeal joint through a window over the lateral side of the joint. (*Bottom, left*) Relation of the insertion of the apparatus into the proximal interphalangeal joint with the apparatus divided transversely over the dorsum of the proximal phalanx. Showing the intimate connection of the apparatus to the sides of the joint. (*Bottom, right*) Relation of the apparatus to the distal phalanx and the sides of the joint. The apparatus is divided at the middle phalanx, and the dorsum of the proximal joint is dissected. This shows the insertion of the central portion of the extensor into the ridge and the tubercle of the middle phalanx. It also shows the relation of the apparatus to the sides of the proximal joint.

ridge distal to the articular cartilage of the base of the distal phalanx from one collateral ligament to the other. The insertion expands over the entire dorsum of the phalanx underneath the nail bed and the root of the nail. (Fig. 4)

Over the dorsum of the proximal interphalangeal joint, transverse and arciform fibers, running across the insertion of the middle part of the lateral bands of the dorsal expansion, anchor the whole expansion to the lateral collateral ligaments and sides of

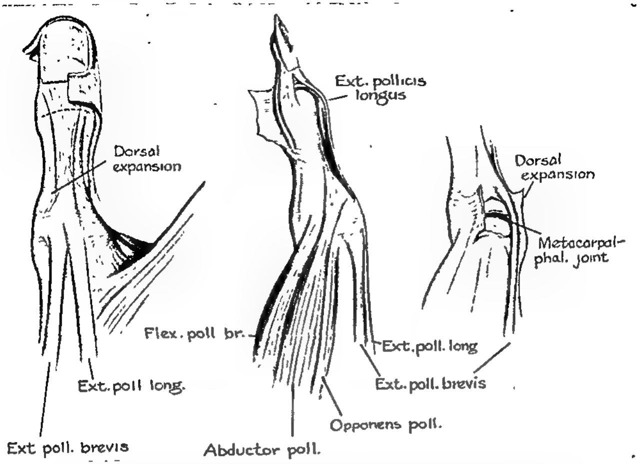


FIG. 5. Extensor apparatus of the thumb. Illustrates the close relation of the skin and the nail to the extensor insertion at the distal phalanx, also the structure of the tendons of the abductor brevis and adductor to the expansion and the anchorage of the apparatus to the metacarpophalangeal and the interphalangeal joints.

the volar plate of the proximal interphalangeal joint. The direction and the location of these fibers are similar to the fibers of the dorsal apparatus over the metacarpophalangeal joint, and their function is similar. They anchor the apparatus to the corresponding joint and contribute to the relative independence of action of the mid-portion of the extensor communis tendon and the lateral bands. The lateral bands transmit action to the middle and the distal phalanges, when the central portion of the extensor communis tendon ceases to act; the central portion of the extensor communis tendon transmits its action when the lateral bands are tensed to the maximum by their motors (interossei and lumbricals), or when they are completely relaxed.

Dorsal Apparatus of the Thumb

The extensor apparatus over the metacarpophalangeal joint of the thumb represents a complex that includes the extensor pollicis longus and the extensor pollicis brevis, crossed by arciform fibers connected with expansions from the abductor pollicis brevis and the adductor pollicis. The extensor pollicis longus runs in the depth of the dorsal apparatus on the ulnar side of the metacarpophalangeal joint. Then it expands, forming a wide band in its course to the distal phalanx. (Fig. 5)

The extensor pollicis brevis runs deeper in the dorsal apparatus, almost over the middle of the metacarpophalangeal joint. Not infrequently, a longitudinal expansion from the extensor pollicis brevis joins the broadened

tendon of the extensor pollicis longus in its course to the distal phalanx. In this case, contractions of the extensor pollicis brevis may produce extension of the distal phalanx, when the first metacarpal is abducted from the second metacarpal. Arciform fibers that emanate from the insertion of the abductor pollicis brevis cross the two extensor tendons and meet similar, but somewhat less pronounced, fibers coming from the insertion of the adductor pollicis. Thus, the extensor apparatus is anchored to the sides of the metacarpophalangeal unit, permitting longitudinal motion of the long and the short extensors of the thumb.

The arciform fibers from the abductor pollicis brevis and the adductor pollicis transmit their action to the distal phalanx, producing extension of the distal phalanx. This extension of the distal phalanx can be observed in cases of paralysis of the long and the short extensors of the thumb when the patient uses the thenar muscles to oppose the thumb. It can also be observed in cases of traumatic division of the long and the short extensors of the thumb proximal to the metacarpophalangeal joint; then opposition of the thumb produces also extension of the distal phalanx.

At the interphalangeal joint of the thumb, the extensor apparatus spreads over the entire width of the base of the dorsum of the distal phalanx. It is connected intimately with the capsule of the joint. The expansion of the dorsal apparatus of the thumb has no lateral bands, but it has distinct edges on each side, more visible on the radial side of the apparatus. These edges are in continuation with the expansions of the abductor pollicis brevis on the radial side and the adductor pollicis on the ulnar. (Fig. 4)

FUNCTION OF THE DORSAL APPARATUS

Extensor Digitorum Communis and the Intrinsic Muscles

The dorsal apparatus is extended so that it is volar to the flexion extension axis of

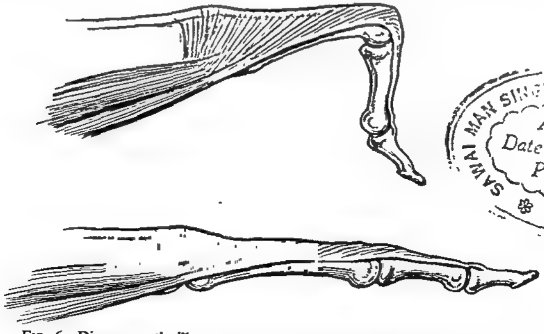


Fig. 6. Diagrammatic illustration of the extensor apparatus, which is tense over the proximal phalanx, the metacarpophalangeal joint and the proximal interphalangeal joint when the proximal joint is flexed and the metacarpophalangeal joint is extended. This is the position in which mallet-finger deformities frequently are treated and should not be. The entire extensor apparatus is relaxed when all 3 joints are kept in moderate extension. The lateral bands are dorsal to the axis of flexion and extension over the proximal interphalangeal joints in both instances.

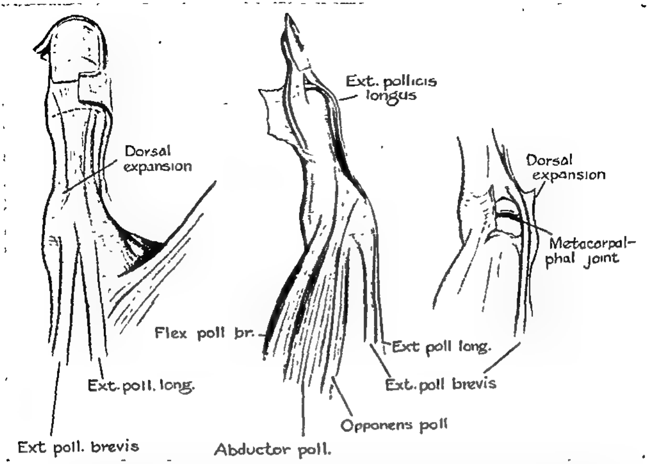


FIG. 5. Extensor apparatus of the thumb. Illustrates the close relation of the skin and the nail to the extensor insertion at the distal phalanx, also the structure of the tendons of the abductor brevis and adductor to the expansion and the anchorage of the apparatus to the metacarpophalangeal and the interphalangeal joints.

the volar plate of the proximal interphalangeal joint. The direction and the location of these fibers are similar to the fibers of the dorsal apparatus over the metacarpophalangeal joint, and their function is similar. They anchor the apparatus to the corresponding joint and contribute to the relative independence of action of the mid-portion of the extensor communis tendon and the lateral bands. The lateral bands transmit action to the middle and the distal phalanges, when the central portion of the extensor communis tendon ceases to act; the central portion of the extensor communis tendon transmits its action when the lateral bands are tensed to the maximum by their motors (interossei and lumbricals), or when they are completely relaxed.

Dorsal Apparatus of the Thumb

The extensor apparatus over the metacarpophalangeal joint of the thumb represents a complex that includes the extensor pollicis longus and the extensor pollicis brevis, crossed by arciform fibers connected with expansions from the abductor pollicis brevis and the adductor pollicis. The extensor pollicis longus runs in the depth of the dorsal apparatus on the ulnar side of the metacarpophalangeal joint. Then it expands, forming a wide band in its course to the distal phalanx. (Fig. 5)

The extensor pollicis brevis runs deeper in the dorsal apparatus, almost over the middle of the metacarpophalangeal joint. Not infrequently, a longitudinal expansion from the extensor pollicis brevis joins the broadened

tendon of the extensor pollicis longus in its course to the distal phalanx. In this case, contractions of the extensor pollicis brevis may produce extension of the distal phalanx, when the first metacarpal is abducted from the second metacarpal. Arciform fibers that emanate from the insertion of the abductor pollicis brevis cross the two extensor tendons and meet similar, but somewhat less pronounced, fibers coming from the insertion of the adductor pollicis. Thus, the extensor apparatus is anchored to the sides of the metacarpophalangeal unit, permitting longitudinal motion of the long and the short extensors of the thumb.

The arciform fibers from the abductor pollicis brevis and the adductor pollicis transmit their action to the distal phalanx, producing extension of the distal phalanx. This extension of the distal phalanx can be observed in cases of paralysis of the long and the short extensors of the thumb when the patient uses the thenar muscles to oppose the thumb. It can also be observed in cases of traumatic division of the long and the short extensors of the thumb proximal to the metacarpophalangeal joint; then opposition of the thumb produces also extension of the distal phalanx.

At the interphalangeal joint of the thumb, the extensor apparatus spreads over the entire width of the base of the dorsum of the distal phalanx. It is connected intimately with the capsule of the joint. The expansion of the dorsal apparatus of the thumb has no lateral bands, but it has distinct edges on each side, more visible on the radial side of the apparatus. These edges are in continuation with the expansions of the abductor pollicis brevis on the radial side and the adductor pollicis on the ulnar. (Fig. 4)

FUNCTION OF THE DORSAL APPARATUS

Extensor Digitorum Communis and the Intrinsic Muscles

The dorsal apparatus is extended so that it is volar to the flexion extension axis of

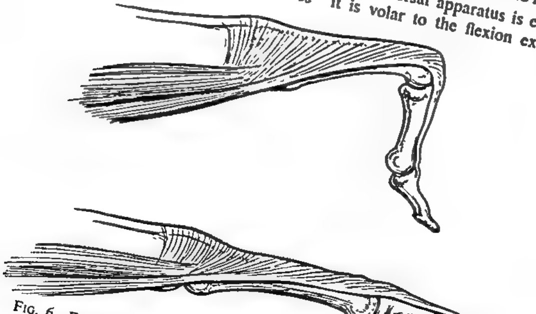


Fig. 6. Diagrammatic illustration of the extensor apparatus, which is tense over the proximal phalanx, the metacarpophalangeal joint and the proximal interphalangeal joint when the proximal joint is flexed and the metacarpophalangeal joint is extended. This is the position in which mallet-finger deformities frequently are treated and should not be. The entire extensor apparatus is relaxed when all 3 joints are kept in moderate extension. The lateral bands are dorsal to the axis of flexion and extension over the proximal interphalangeal joints in both instances.

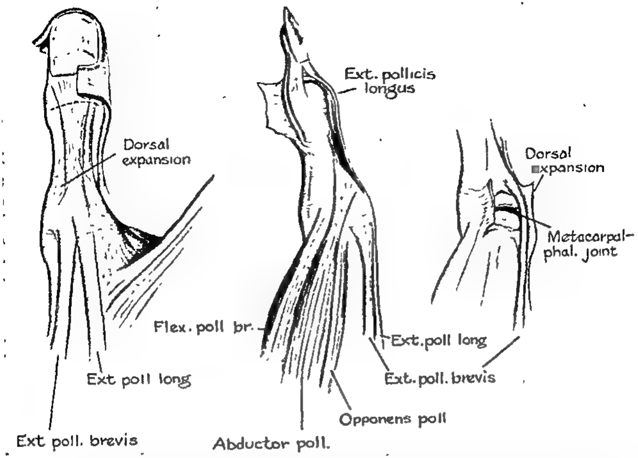


FIG. 5. Extensor apparatus of the thumb. Illustrates the close relation of the skin and the nail to the extensor insertion at the distal phalanx, also the structure of the tendons of the abductor brevis and adductor to the expansion and the anchorage of the apparatus to the metacarpophalangeal and the interphalangeal joints.

the volar plate of the proximal interphalangeal joint. The direction and the location of these fibers are similar to the fibers of the dorsal apparatus over the metacarpophalangeal joint, and their function is similar. They anchor the apparatus to the corresponding joint and contribute to the relative independence of action of the mid-portion of the extensor communis tendon and the lateral bands. The lateral bands transmit action to the middle and the distal phalanges, when the central portion of the extensor communis tendon ceases to act; the central portion of the extensor communis tendon transmits its action when the lateral bands are tensed to the maximum by their motors (interossei and lumbricals), or when they are completely relaxed.

Dorsal Apparatus of the Thumb

The extensor apparatus over the metacarpophalangeal joint of the thumb represents a complex that includes the extensor pollicis longus and the extensor pollicis brevis, crossed by arciform fibers connected with expansions from the abductor pollicis brevis and the adductor pollicis. The extensor pollicis longus runs in the depth of the dorsal apparatus on the ulnar side of the metacarpophalangeal joint. Then it expands, forming a wide band in its course to the distal phalanx. (Fig. 5)

The extensor pollicis brevis runs deeper in the dorsal apparatus, almost over the middle of the metacarpophalangeal joint. Not infrequently, a longitudinal expansion from the extensor pollicis brevis joins the broadened

tendon of the extensor pollicis longus in its course to the distal phalanx. In this case, contractions of the extensor pollicis brevis may produce extension of the distal phalanx, when the first metacarpal is abducted from the second metacarpal. Arciform fibers that emanate from the insertion of the abductor pollicis brevis cross the two extensor tendons and meet similar, but somewhat less pronounced, fibers coming from the insertion of the adductor pollicis. Thus, the extensor apparatus is anchored to the sides of the metacarpophalangeal unit, permitting longitudinal motion of the long and the short extensors of the thumb.

The arciform fibers from the abductor pollicis brevis and the adductor pollicis transmit their action to the distal phalanx, producing extension of the distal phalanx. This extension of the distal phalanx can be observed in cases of paralysis of the long and the short extensors of the thumb when the patient uses the thenar muscles to oppose the thumb. It can also be observed in cases *of traumatic division of the long and the* short extensors of the thumb proximal to the metacarpophalangeal joint; then opposition of the thumb produces also extension of the distal phalanx.

At the interphalangeal joint of the thumb, the extensor apparatus spreads over the entire width of the base of the dorsum of the distal phalanx. It is connected intimately with the capsule of the joint. The expansion of the dorsal apparatus of the thumb has no lateral bands, but it has distinct edges on each side, more visible on the radial side of the apparatus. These edges are in continuation with the expansions of the abductor pollicis brevis on the radial side and the adductor pollicis on the ulnar. (Fig. 4)

FUNCTION OF THE DORSAL APPARATUS

Extensor Digitorum Communis and the Intrinsic Muscles

The dorsal apparatus is extended so that it is volar to the flexion extension axis of

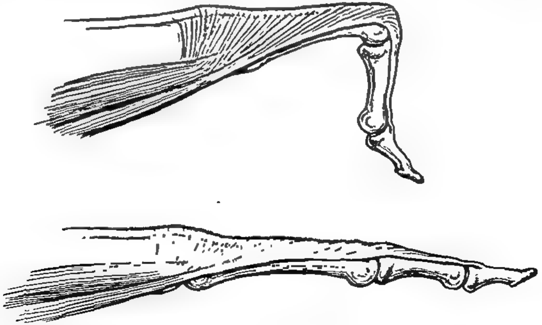


Fig. 6. Diagrammatic illustration of the extensor apparatus, which is tense over the proximal phalanx, the metacarpophalangeal joint and the proximal interphalangeal joint when the proximal joint is flexed and the metacarpophalangeal joint is extended. This is the position in which mallet-finger deformities frequently are treated and should not be. The entire extensor apparatus is relaxed when all 3 joints are kept in moderate extension. The lateral bands are dorsal to the axis of flexion and extension over the proximal interphalangeal joints in both instances.

the finger at the metacarpophalangeal joint. It is located dorsally to the axis of the extension and the flexion at the proximal and the distal interphalangeal joints. Any traction applied to the extensor digitorum communis tendon, proximal to the metacarpophalangeal joint, will produce extension and hyperextension of the proximal phalanx, slight extension of the middle phalanx and very slight extension of the distal.

If the lumbrical and the interossei are stimulated while the extensor digitorum communis tendon is maintained in maximum extension, the relative independence of the lateral bands, through which action is transmitted, permits further extension of the middle and the distal phalanges.

If the extensor communis tendon is left relaxed, but the interossei and the lumbricals are stimulated, the metacarpophalangeal joint flexes strongly, because the pull of the intrinsic muscles runs volar to the axis of flexion and extension at the metacarpophalangeal joint. However, the middle and the distal phalanges extend strongly through action on the lateral bands that are dorsal to the axis of flexion and extension over the proximal and the distal interphalangeal joints. (Fig. 6)

Experiments on the cadaver and stimulation of muscles under different conditions, also observation of action of the exposed dorsal apparatus under brachial block anesthesia, reveal very interesting facts.

Under normal conditions the lumbrical muscles do not produce abduction of the index and the middle fingers, nor adduction of the ring and the fifth. They cannot produce lateral deviation because all their functional length is taken up by extension of the two distal joints and flexion of the metacarpophalangeal joint. Abduction and adduction of the fingers, when they are extended, are produced mostly by the interossei.

When a fist is made, the long flexors produce adduction of the fingers; when the fingers are extended, the long extensors produce abduction of the fingers. The interossei produce simultaneous flexion of the metacarpophalangeal joints with lateral deviation.

In a normal hand, surgical exposure of the dorsal apparatus under local anesthesia shows the following: When the finger is held passively in straight extension in all the three joints, the entire dorsal apparatus is relaxed; when the proximal phalanx is hyperextended passively, the dorsal apparatus over the metacarpophalangeal joint becomes tense. It is also tense over the proximal interphalangeal joint but is relaxed over the distal interphalangeal joint. If, however, the metacarpophalangeal joint is held hyperextended passively and the proximal interphalangeal joint is hyperextended by the examiner, the entire dorsal apparatus is tense but the distal phalanx then can be flexed and extended almost completely actively by the patient. If the metacarpophalangeal joint and the proximal interphalangeal joint are both held strongly flexed by the examiner, the entire apparatus becomes completely relaxed over the three joints, and the patient is unable to flex or to extend the distal phalanx.

In the cadaver, the position of hyperextension of the metacarpophalangeal joint and flexion of the proximal interphalangeal joint produces tension of the entire dorsal apparatus with slight relaxation of the apparatus over the distal phalanx. Placing the finger in neutral position in the three joints produces complete relaxation of the entire dorsal apparatus over the three joints. (Fig. 6)

The experiments indicate that the condition of the extensor apparatus over the metacarpophalangeal and the interphalangeal joints depends on the state of tension of the central portion of the extensor communis tendon and the comparatively independent lateral bands. Complete active extension of the distal phalanx by the lateral bands is possible when the extensor communis is exerting its action by stabilizing the proximal and the middle phalanges; or when simultaneously the lateral bands stabilize the

metacarpophalangeal joint in flexion (in the absence of an active extensor communis) and act on the distal phalanx.

These experiments also demonstrate that fixation of the proximal interphalangeal joint in flexion and the distal phalanx in extension, in treatment of mallet-finger deformities, is not based on clear visualization of the status of the entire dorsal apparatus over the finger, when active use of the motion of the finger is eliminated. The dorsal apparatus is moderately relaxed over the metacarpophalangeal, the proximal and the distal interphalangeal joints when the finger is held in moderate extension, as if supported on a flat surface. In this position, with elimination of active participation of the finger motors, the relaxation of the dorsal apparatus over the three finger joints is at optimum. (Fig. 6)

The action of the dorsal apparatus cannot be conceived without the participation of the long flexors.

At the metacarpophalangeal joint the long flexors act synergistically with the intrinsic muscles; they exert their action on the metacarpophalangeal joint after having produced their main function, namely, flexion of the distal phalanx by the flexor profundus and flexion of the proximal interphalangeal joint by the flexor sublimis. At the distal interphalangeal joint the flexor profundis is counterbalanced by the distal insertion of the dorsal apparatus. At the proximal interphalangeal joint the flexor sublimis is counterbalanced by the central part of the extensor digitorum communis inserted into the base of the middle phalanx. Thus the finger presents a triple-functioning system in which the metacarpophalangeal and each interphalangeal joint are acted upon by opposing forces In addition, it has a regulating factor between the flexor and the extensor system represented by the lumbrical muscle. The lumbrical muscle is primarily a flexor of the metacarpophalangeal and extensor of the proximal and the distal interphalangeal joints. It also forms a link between the extensor and the flexor components of the finger and regulates simultaneously flexion and extension of the distal phalanx. When the tendon of the flexor profundus produces flexion of the distal phalanx, the lumbrical, originating from this tendon, may simultaneously extend the distal phalanx, stabilizing the distal interphalangeal joint. When rapid extension of the distal phalanx is required, contraction of the lumbrical produces not only extension of the distal phalanx but also distal advancement of the flexor profundus, thus relieving tension on the insertion of the flexor profundus.

Function of the Dorsal Apparatus of the Thumb

The dorsal apparatus of the thumb is so constructed that there is comparative independence of the extensor pollicis longus. This produces simultaneous extension at the interphalangeal, the metacarpophalangeal and the metacarpocarpal joints with adduction of the first metacarpal. The extensor brevis produces extension of the metacarpophalangeal joint but acts mostly as an abductor of this joint. In occasional cases it may act as an extensor of the distal phalanx, but mostly when the thumb is abducted. The dorsal apparatus, which anchors the entire unit to the sides of the metacarpophalangeal joint, balances its to-and-fro motion over the central longitudinal axis of this joint. The contraction of the thenar muscles permits independent extension of the distal phalanx in the absence of action of the long and the short extensors of the thumb, but this is possible only when the thumb is in opposition.

INJURIES TO THE DORSAL APPARATUS

Dorsum of the Hand

The mechanism of the dorsal apparatus is so delicately balanced that the slightest change over one joint interferes with the function of the others. Traumatic interruptions of the dorsal apparatus itself are not

the only factors affecting the function. Skeletal minimal trauma, congenital and systemic diseases, may produce the same typical deformities.

Division of separate extensor tendons or the entire extensor apparatus over the dorsum of the hand requires simple suture of the tendons with any suitable material. White silk is advisable, because not infrequently black silk sutures may be visible in individuals with thin skin covering the dorsum.

In cases of congenital limitation of extension of the ring or the middle finger it is not advisable to treat this condition by division of the juncturae tendinum because, as shown above, the limitation is not produced by the juncturae. (Fig. 1)

In multiple division of the tendons it is advisable to unite meticulously the corresponding ends. In attrition of some of the tendons, due to arthritis or old fractures, it is preferable to transfer one of the proprii if possible. The incisions over the dorsum of the hand are curved along the long axis or placed obliquely across. The oblique incisions heal better than the transverse or even the curved over the dorsum of the hand.

Injuries to the Dorsum of the Metacarpophalangeal Joint, Excluding the Thumb

The division of the apparatus may be longitudinal and involve one side only without affecting the extensor tendon. In the presence of a transverse injury or division of the tendon of the extensor digitorum communis of the middle or the ring finger, the metacarpophalangeal joint cannot be extended by will. The joint of the involved finger is kept slightly more flexed than the other fingers are when at rest. When an attempt is made to extend the entire finger, the metacarpophalangeal joint flexes instead, and the two distal phalanges extend. The little and the index fingers may have active extension of the proximal phalanx when only the extensor communis tendon to each of these fingers is divided However, it is preferable to repair surgically traumatic division of the extensor communis to these two fingers, even though the fingers can be extended actively. Division of both communis and proprius tendons requires a separate accurate repair of each tendon.

When the dorsal apparatus is divided longitudinally on one side or the other of the extensor tendon over the metacarpophalangeal joint, the extensor tendon luxates to the uninjured side, pulling over the proximal phalanx. Normal extension becomes impossible. The action of the intrinsic muscles is disturbed. The middle and the distal phalanges cannot be completely extended and remain partially flexed. In the presence of a simple transverse division of the extensor tendon, a meticulous repair, using silk or any other nonirritating material, is necessary. Pull-out sutures are very useful.

When the entire dorsal apparatus is involved from side to side, it is necessary to explore each side of the metacarpophalangeal joint and repair the division of the tendons of the interossei and the lumbricals separately. The tendon of the extensor digitorum communis must also be repaired separately. A few fine sutures are placed to reconstruct the dorsal expansion.

Side injuries of the extensor apparatus require precise repair of the defect in fresh cases, making certain that the extensor communis tendon is directly over the joint. In older cases, where the extensor tendon is luxated and cannot be replaced easily, it is necessary to reduce the luxation of the tendon and place it exactly over the metacarpophalangeal joint. This may require undercutting and freeing of the apparatus on the other side. After the tendon is placed in its normal position, passive flexion and extension of the metacarpophalangeal joint must be tested to prove that the tendon remains in place.

After surgical repair of any part of the extensor apparatus, the hand must be placed in slight extension at the wrist and all the

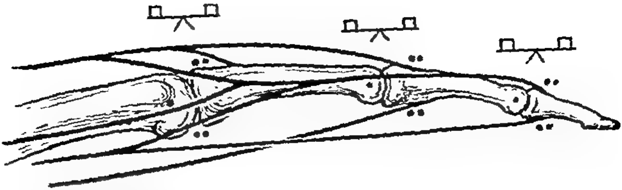


FIG. 7. Diagrammatic illustration of the balance of forces over the joints of the finger. The single dots represent the axis of flexion-extension of each joint. The double dots represent the areas of action of the corresponding tendons at each joint. At the metacarpophalangeal joint the balance is between the extensor tendon on the dorsum and the interosseous lumbrical component at the volar aspect. At the proximal joint the insertion of the extensor apparatus into the dorsum of the middle phalanx is balanced against the flexor sublimis. At the distal joint the insertion of the extensor apparatus is balanced against the flexor profundus.

fingers. This position must be maintained in plaster-of-Paris fixation for 3 weeks at least.

Injuries to the Dorsum of the Proximal Interphalangeal Joint

Injuries to the dorsum of this joint produce a typical deformity that increases before it becomes stable. The joint is flexed at 85° to 90°, while the distal phalanx is fixed in hyperextension. The patient is unable to extend the middle phalanx; passively it can be extended slightly. Further flexion of the middle phalanx can be performed actively. The distal phalanx cannot be flexed actively, or even passively. This deformity is commonly known as a "buttonhole," or "boutonnière," finger, and was explained by a protrusion of the proximal phalanx through the extensor apparatus, with sliding of the lateral bands volar to the extension-flexion axis of the proximal interphalangeal joint. Actually, the cause of the deformity is complex and may be due to several factors.

When acquired by acute trauma or laceration, it may be due to severance of the central part of the extensor communis. In this case the balance between the extensor communis insertion at the base of the middle phalanx and the flexor sublimis, inserted into the volar aspect of the middle phalanx, is broken. The unopposed flexor sublimis flexes the middle phalanx; the flexor profundus loses its normal length in relation to the sublimis. The origin of the lumbrical retracts, extending the distal phalanx, because of disruption of the oblique fibers over the proximal joint. If this type of laceration of the extensor communis is not repaired soon after injury, flexion contracture develops. The retraction of the lumbrical becomes fixed, causing contracture of the distal phalanx in extension. When the contractures are well established, corrective surgery of this deformity becomes a major task for the most skillful surgeon. The problem of correction requires restoration of the entire width of insertion of the extensor communis into the base of the middle phalanx, recreation of the obliquity of the connecting fibers of the dorsal extension apparatus over the joint, and release of the contracture of the lateral bands. The extension contracture of the distal phalanx may improve slowly if proper correction is obtained at the proximal interphalangeal joint.

The deformity may also be due to severe arthritis of the proximal interphalangeal joint.

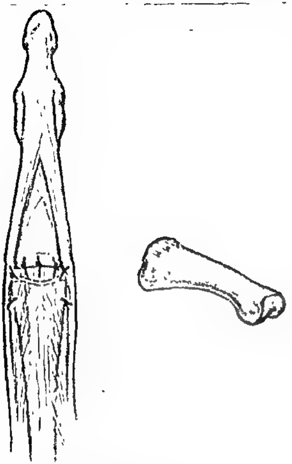


FIG. 8 Method of repair that is useful in certain cases of division of the extensor apparatus at the proximal interphalangeal joint.

A similar deformity may result in certain cases of complete avulsion of the flexor profundus at the base of the distal phalanx. However, this modality can be differentiated easily from an injury to the extensor apparatus at the proximal interphalangeal joint, because the distal phalanx is extended but the extension is not fixed and can easily be overcome passively. Flexion of the proximal interphalangeal joint in these cases develops because the retracted profundus, held by the vincula, acts on the middle phalanx together with the sublimis, thus overbalancing the action of the extensor communis on the middle phalanx and causing flexion of this joint (Fig. 7)

A third group of this deformity is observed as a congenital flexion of the proximal interphalangeal joint mostly of the little finger. The results of correction of the congenital deformity are most unsatisfactory. The reason for this failure lies in the peculiar pathology. The deformity is found to be caused by several factors. The most important is absence of insertion of the extensor communis into the base of the proximal phalanx. Absence of the flexor profundus and capsular contractures of the volar plate of the proximal joint with flexion contracture of the sublimis may also be observed. A synostosis or a synchondrosis of the proximal interphalangeal joint or a congenital flexor sublimis contracture is found occasionally. It is accompanied frequently by skin contractures.

It is extremely difficult to correct congenital deformities. Inasmuch as the reasons for deformities are multiple, and there is nothing to resemble a buttonhole, or boutonnière, it might be better to eliminate this name from the terminology.

In cases of fresh or recent injury, the treatment consists of reattachment of the lacerated tendon if possible. The incision is best placed obliquely over the proximal interphalangeal joint. It is imperative to reestablish the insertion from one lateral band to the other over the entire width of the base of the proximal phalanx. If no tendon tissue is left for suture over the ridge of insertion, several drill holes perpendicular to this ridge can be made, using the finest drill point. The central part of the extensor communis is sutured to the ridge through these drilled tunnels with silk. The central portion of the tendon is sutured to each lateral band immediately proximal to the joint line and at the level of reinsertion of the extensor digitorum communis. (Fig. 8) One suture on each side is placed proximal to the joint and one suture on each side distal to the joint. The proximal interphalangeal joint is transfixed carefully in full extension by two thin cross wires before the actual suturing is done. All the fingers are placed on a plaster-of-Paris splint over the

palm of the hand and the fingers in moderate extension at the metacarpophalangeal and the interphalangeal joints and fixed with a circular plaster-of-Paris bandage for 2 weeks. The splint is removed after 2 weeks, and the skin sutures are extracted. The involved finger is placed again in a plaster-of-Pairs circular bandage; it is held in extension at the three joints. The wires and the second plaster of Paris are removed in 5 weeks after the operation, when gradual normal use of the fingers is encouraged.

In cases of complete division of the dorsal apparatus an attempt to unite accurately the ends of each lateral band should be made in addition to the restoration of the central part. The joint is transfixed with wires, and fixation is applied as described above. In cases of loss of skin associated with tendon injury, skin transplantation covering the joint is most important as the primary procedure. The joint should be transfixed in extension by cross wires at the time of skin transplantation.

Following a successful repair, the suture material uniting the apparatus shows a tendency to extrude. The removal of these sutures after several weeks does not vitiate a successful repair.

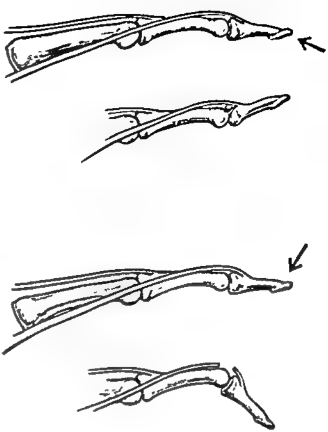


FIG. 9. Diagrammatic illustration of injury produced by striking the tip of the distal phalanx directly when a subtendinous fracture of the base of the distal phalanx is produced without avulsion of the insertion. When the distal phalanx is struck from the dorsal aspect, an avulsion is produced either without or with a small fragment of bone.

Injuries to the Dorsal Apparatus of the Distal Interphalangeal Joint

Injuries affecting the dorsal apparatus of the distal phalanx are known commonly as mallet or baseball fingers. The patient cannot actively extend the distal phalanx, which is flexed. Secondary hyperextension of the proximal interphalangeal joint develops shortly after. The patient cannot flex the proximal joint rapidly. Although there is no limitation of flexion, the normal smoothness of flexion is lost.

Mallet-finger deformities develop as a result of several causes: (1) The extensor apparatus may be divided with a sharp instrument near the distal joint, or between the distal and the proximal joints. (2) A subcutaneous avulsion may occur when the extended distal phalanx is struck by an object over its dorsal side. Then the tendon is torn off with a chip of bone. (3) The extended distal phalanx may be struck directly over the tip, causing a fracture of the dorsal base of the distal phalanx without avulsion or tear of the tendon (Fig. 9). (4) In children 12 to 14 years of age the basal epiphysis of the distal phalanx may be fractured in two equal or unequal fragments. The tendon is not avulsed, but a typical mallet-finger deformity follows. (5) In patients with arthritis, typical mallet-finger deformities occur as a result of arthritic involvement of the joint surfaces without avulsion of the tendinous apparatus.

In cases of subtendinous fractures, not only is the distal phalanx flexed but it may be deviated to either side.

The development of the deformity in cases of laceration is due to the following mechanism: The normal balance that exists between the flexor profundus and the extensor apparatus at the base is broken. The flexor profundus, acting on the distal phalanx, has no opposition; it produces flexion of the distal phalanx. On the other hand, the flexor sublimis normally has its counterbalancing factor in the central portion of the extensor communis inserted into the dorsal base of the middle phalanx. The dorsal insertion of the distal phalanx retracts its action to the area of the base of the middle phalanx, where it is connected by the transverse and the oblique fibers. Thus the dorsum of the middle phalanx has a double extensor factor against the single factor of the flexor sublimis. This produces the typical hyperextension of the middle phalanx that accompanies flexion of the distal phalanx. (Fig. 7)

In cases of subtendinous fractures at the base of the distal phalanx without laceration of the extensor apparatus, the displaced fragment lands between the extensor apparatus and the base of the phalanx. It interferes with normal extension and permits overaction of the flexor profundus, leading to a mallet-finger deformity.

Treatment of mallet-finger deformities depends on the type and the length of time that has elapsed since injury.

In the author's experience, fresh subcutaneous lacerations of the extensor insertion are best treated in the following simple manner: An elastic adhesive plaster is cut in strips of about ¾-inch widths and wound without tension around the injured finger from the tip of the distal phalanx to the interdigital fold. A plaster-of-Paris bandage of the same width is applied over the elastic adhesive with the distal phalanx in slight hyperextension and the proximal phalanx in normal extension. The finger is held in this position until the plaster of Paris has hardened securely. This bandage, properly applied, stays on for 5 to 6 weeks. The metacarpophalangeal joint is free to move. The bandage is inspected frequently and reinforced if necessary, so that the position of the finger does not change and the plaster of Paris remains in the same position for the entire period of treatment. On removal of the plaster of Paris in 6 weeks, the deformity is found to be corrected in most cases. The principle of the treatment is to secure fixation of the entire dorsal apparatus from the proximal phalanx to the tip of the distal phalanx with moderate relaxation of the extensor apparatus, which is possible only when the finger is in the extended position at the proximal interphalangeal joint.

Treatment of this deformity with wire fixation through the distal phalanx with the proximal interphalangeal joint in flexion produces too much tension of the extensor apparatus over the proximal interphalangeal joint and the proximal phalanx, causing secondary contractures.

It was also observed that even in comparatively old cases of several months' duration of subcutaneous rupture of the insertion of the distal phalanx, immobilization of the finger as described above might produce satisfactory results.

In cases of subcutaneous avulsion of the extensor apparatus with roentgenographic evidence of a small undisplaced fragment, the same method of treatment is applicable.

In cases of fracture of the base with a large displaced fragment, open reduction through an oblique incision placed over the dorsum of the joint is indicated. Replacement of the fragment may be difficult, but, with careful dissection and removal of scar tissue, reduction can be accomplished. It is sometimes advisable to retain the fragment in the optimum position with a pull-out wire. It transfixes the fragment to the base of the distal phalanx, then is brought out anteriorly through the volar pulp and fixed on a button. If the fragment is very small and cannot be replaced, it is better to remove it.

In cases of injury to the epiphyseal plate of the base in adolescents, open reduction

should be avoided and plaster of Paris adhesive plaster immobilization in the extended position of the distal and the proximal interphalangeal joint used.

In cases of fresh division of the extensor apparatus near the base of the distal phalanx or proximal to the base over the middle phalanx, open *suture of the divided tendon may* be attempted. The finest silk or wire on atraumatic needles should be used. Pull-out sutures are of great help. One may use immobilization for 2 or 3 days until postoperative pain and swelling subside, followed by application of elastic adhesive plaster and plaster of Paris immobilizing the finger at the proximal and the distal interphalangeal joints for 5 weeks in moderate extension.

In old cases of tendon division, open operation may be attempted. Adhesions between the retracted tendon and the periosteum *of the middle phalanx may be difficult* to overcome. Interposition of plaster material, after freeing the adhesions, does not appear to be the answer. If the extensor apparatus can be brought up to the base of the distal phalanx, an attempt to attach it there should be made. The plaster-of-Paris technic as described should follow the operation. Insertion of a wire through the apex of the distal phalanx traversing the distal interphalangeal joint into the middle phalanx is not generally recommended because the proper placing of the wire is difficult. Transfixing *the distal phalanx in extension and the* proximal phalanx in flexion with a wire is difficult without causing injury to the flexor tendons in the region over the proximal phalanx. It is also believed that this position is not physiologically correct, as explained before.

Arthrodesis of the distal phalanx in a functional position of about 15° should always be kept in mind as a last resort.

Injuries to the Dorsal Apparatus of the Thumb

The thumb does not represent the same problems as the other digits of the hand.

In cases of injuries over the metacarpophalangeal joint, it is necessary to re-establish the continuity of the extensor pollicis brevis and longus separately. If an injury involves the expansion of the abductor pollicis brevis or the adductor pollicis, the continuity of the expansion must be restored to prevent weakness of extension of the *distal phalanx in opposition.*

Mallet fingers of the thumb are not observed. But in cases of open laceration over the interphalangeal joint, the distal phalanx drops into flexion and hyperextension of the metacarpophalangeal joint does not usually develop. In those who normally are capable of hyperextending actively the metacarpophalangeal joint of the thumb, a hyperextension of the metacarpophalangeal joint may be observed.

In cases of division of the tendon at the interphalangeal joint, either fresh or delayed, *suture of the divided tendon is necessary.* The thumb must be immobilized in a plaster-of-Paris circular bandage, including the hand. The thumb is placed in adduction and extension for moderate relaxation of the entire extensor apparatus.

SUMMARY

1. A description of the dorsal apparatus of the hand and the digit is presented, certain details being emphasized.

2. The function of the dorsal apparatus over the hand and the digits is explained in normal and abnormal conditions.

3. Treatment of different injuries to the apparatus in various parts of the hand and digits is described.

BIBLIOGRAPHY

Baumann, J. A.: Anatomie fonct[illegible] et chir[illegible]gie de [illegible] des doi[illegible]

Braus, H.: Anatomie des Menschen, Vol. 1, Bewegungsapparat Auflage, p. 331, Berlin, Springer, 1954.

Bunnell, S.: Surgery of the Hand, ed. 3, p. 552, [illegible]

[illegible] (translated by L. B. Kaplan), Philadelphia, Lippincott, 1949.

Ender, J., Krotscheck, H., and Simon-Weidner, R.: Die Chirurgie der Handverletzungen, p. 100, Vienna, Springer, 1956.

Haines, R. W.: The extensor apparatus of the finger, J. Anat. 85:251, 1951.

Iselin, M.: Chirurgie de la main, Livre du chirurgien, ed. 2, p. 266, Paris, Masson, 1955.

Iselin, M., Gosse, L., Boussard, S., and Benoist, D.: Atlas de technique opératoire, chirurgie de la main, p. 178, Paris, Flammarion, 1958.

Kaplan, E. B.: Embryological development of the tendinous apparatus of the fingers, J. Bone & Joint Surg. 32A:820, 1950.

———: Extension deformities of the proximal interphalangeal joints of the fingers, J. Bone & Joint Surg. 18:781, 1936.

———: Functional significance of the insertions of the extensor digitorum communis in man, Anat. Rec. 92:293, 1945.

———: Functional and Surgical Anatomy of the Hand, Philadelphia, Lippincott, 1953.

———: Mallet or baseball finger, Surgery 7:784, 1940.

———: Pathology and operative correction of finger deformities due to injuries and contractures of the extensor digitorum tendon, Surgery 6:35, 1939.

———: The relation of the extensor digitorum communis tendon to the metacarpophalangeal joint, Bull. Hosp. Joint Dis. 6:149, 1945.

Landsmeer, J. M. F.: The anatomy of the dorsal aponeurosis of the human finger and its functional significance, Anat. Rec. 104:31, 1949.

Mason, M. L.: Rupture of tendons of the hands. With a study of the extensor tendon insertions in the fingers. Surg., Gynec. & Obst. 50:611, 1930.

Montant, R., and Baumann, A.: Ruptures-luxation de l'appareil extenseur des doigts au niveau de la première articulation phalangienne, Rev. orthop. 25:4, 1938.

Nichols, H. M.: Manual of Hand Injuries, Chicago, Year Book Pub., 1955.

Nomina Anatomica: Submitted and approved by the Sixth International Congress in Paris, 1955.

O'Rahilly, R.: The Developmental Anatomy of the Digital Extensor Assembly. Reported at the 66th annual session of the American Association of Anatomists, Columbus, 1953.

Paturet, G.: Traité d'Anatomie Humaine, vol. 2, p. 290, Paris, Masson, 1951.

Pratt, D. R., Bunnell, S., and Howard, L. D.: Mallet finger classification and method of treatment, Am. J. Surg. 93:573, 1957.

Rank, B. K., and Wakefield, A. R.: Surgery of Repair As Applied to Hand Injuries, p. 179, Edinburgh, Livingstone, 1953.

Sunderland, E.: The action of the extensor digitorum communis, interosseous and lumbrical muscles, Am. J. Anat. 77:189, 1945.

Watson-Jones, R.: Fractures and Joint Injuries, ed. 4, p. 645, Baltimore, Williams & Wilkins, 1955.

Anatomia, Lesiones e Tractamento del Apparato Extensori del Mano e Digitos

Summario in Interlingua

Le apparato extensori del mano e digitos ha un structura complexe super le dorso del mano e del digitos.

Le extensor commun del digitos, in consequentia del arrangiamento de su corpore muscular, limita le independentia extensional del digitos individual (i.e. del indice e del digitos annular, medie, e minime). Le extensores proprie permitte le extension libere del indice e del digito minime. Le juncturas de tendines ha un rolo secundari in le limitation del extension del digito annular e del digito medie.

Le apparato extensori de omne digito individual es un structura unificate e integrate que es dividite artificialmente in partes separate, principalmente pro objectivos de description anatomic. Omne parte functiona in intime relation con le altere partes del apparato ab le dorso del mano usque al puncta del phalange distal.

Le apparato dorsal es le producto final del convergentia del extensor longe e del tendines intrinsec, co-ligate e connectite—per fibras transverse e oblique—con le articulationes metacarpophalangee, proximal, e distal e le retinaculos del flexores de iste articulationes.

Lesiones del apparato dorsal supra le varie articulationes resulta in deformitates typic. Le interpretation del mechanismo de iste deformitates non es simple in omne

casos. Le correction require un cognoscentia detaliate del structura e physiologia del apparato in su totalitate.

Le tractamento debe esser conservative, non-mutilante, e precise. Illo differe pro omne digito individual. Correctiones in le caso del digito annular e del digito medie, specialmente supra le articulation metacarpophalangee es forsan un pauco plus simple. Correctiones del digito minime es plus difficile. Le pollice require methodos completemente distincte.

4

The Skeletal Development of the Hand*

RONAN O'RAHILLY, M.D., ERNEST GARDNER, M.D., AND D. J. GRAY, PH.D.†

INITIAL DEVELOPMENT OF THE UPPER LIMB

When the emphasis in the development of the embryo in general shifts from differentiation to growth, the organism is termed a fetus. The embryonic period proper, according to the usage adopted at the Department of Embryology, Carnegie Institution of Washington, comprises the first 7 postovulatory weeks:

> When the human embryo approaches 30 mm. in length a radical change is initiated in the humerus, namely, the transformation of its cartilage into bone marrow. . . . If the onset can be recognized in a given specimen, that specimen is straightway classed as a fetus. . .[37]

The embryonic period, as defined above, has been divided into 23 stages ("developmental horizons"). This system of staging has greatly facilitated preciseness in embryologic descriptions by providing a partial emancipation from timing and from the customary measurements. Indeed, the term *stage* should no longer be used unless a system of staging other than C. R. measurement has been employed.

The limbs first appear as minute buds in embryos of 4 postovulatory weeks. The upper limb buds, which appear very slightly earlier than the lower, are seen in embryos about 3 to 4 mm. in length (Stage 12). The limb buds arise from the nonsegmented lateral body wall (somatopleure) of the embryo (it is believed that there is no contribution from somites) and are derived from two sources: (1) Proliferating mesodermal cells; and (2) a covering of proliferating skin ectoderm. Each limb bud elongates and develops in proximodistal sequence; e.g., the arm appears before the hand. A few days after the limb buds can first be recognized, nerves grow into them.[9] The skeleton (in the form of cartilage) and the muscles become visible (Stage 15), and, shortly afterward, the fingers can be observed (Stage 17). The changing configuration of the developing limbs has been studied in considerable detail.[15,26]

An ectodermal thickening appears on the ventral aspect and the lateral border of the upper limb bud almost as soon (Stage 12) as the bud is visible.[26] A few days later (Stage 14) the lateral part of this thickening forms an ectodermal ridge that disappears within a week (Stage 17). The ridge is a site of great metabolic activity, as judged by histochemical examination.[22] The importance of this ridge has been established experimentally in the case of the chick embryo.[31,32] The mesoderm at the apex of the limb bud progressively lays down the future limb components in proximodistal sequence and in their future spatial pattern; this process is dependent on the ectodermal ridge. The ectodermal ridge is important in mam-

* The embryologic work of the authors has been supported by Research Grants A-532 and A-1644 from the National Institute of Arthritis and Metabolic Diseases of the National Institutes of Health, U. S. Public Health Service.

† [illegible]

mals also.[31] These conclusions are important in the elucidation of many developmental anomalies of the limbs.[24]

The skeletal elements of the limbs are seen first as mesodermal condensations, which soon chondrify in a definite order.[27]

Ossification, in the form of a periosteal collar in tubular bones, occurs subsequently. In the clavicle, the scapula (probably), the humerus, the radius, the ulna, and the distal phalanges (sometimes), ossification commences during the embryonic period proper. Vascular invasion of these skeletal elements by one or more periosteal buds and the establishment of centers of endochondral ossification takes place during the fetal period. Vascular invasion of the carpals occurs during the fetal period, whereas endochondral ossification does not begin until after birth.

The various features in the embryonic development of the upper limb are summarized in Table 1. Some of the details of the chondrification and the ossification will now be presented.

PHASE OF CHONDRIFICATION IN THE HAND

The carpus can first be distinguished as condensed mesenchyme at 5 postovulatory weeks of age (Stage 17). A few days later (Stages 18-19) the individual carpals begin to chondrify in a definite sequence. The pisiform, however, is several days later (Stages 19-21) than the other carpal elements.

TABLE 1. EARLY DEVELOPMENT OF UPPER LIMB

Feature	Stage	mm.	Postovulatory Weeks	Authors
Upper limb bud	12	2.5-5.8	4	Streeter, 1942
Ectodermal ridge	14-17	4.9-14.5	4-5	O'Rahilly, Gardner and Gray, 1956
Mesenchymal scapula..	16	9	5	Lewis, 1902
Mesenchymal humerus, radius, ulna	16	7.0-12.2	5	O'Rahilly, Gray and Gardner, 1957
Chondrifying humerus .	16-17	7.0-14.5	5	O'Rahilly, Gray and Gardner, 1957
Chondrifying radius ...	17	8.6-14.5	5	O'Rahilly, Gray and Gardner, 1957
Mesenchymal hand ...	17	8.6-14.5	5	O'Rahilly, Gray and Gardner, 1957
Chondrifying ulna, metacarpus	17-18	8.6-18.0	5	O'Rahilly, Gray and Gardner, 1957
Mesenchymal clavicle..	18	12	5	Lewis, 1902
Ossifying clavicle	?	?-20	5	Zawisch, 1953
Chondrifying proximal phalanges	18-19	11.7-21.0	5-5½	O'Rahilly, Gray and Gardner, 1957
Chondrifying carpus ..	18-20	11.7-25.0	5-6	O'Rahilly, Gray and Gardner, 1957
Chondrifying middle phalanges	19-20	15.5-25.0	5½-6	O'Rahilly, Gray and Gardner, 1957
Chondrifying distal phalanges	20-21	18.5-26.4	6	O'Rahilly, Gray and Gardner, 1957
Ossifying humerus	21-22	19.0-27.5	6-6½	O'Rahilly, Gray and Gardner, 1957
Ossifying radius	21-23	19.0-32.2	6-7	O'Rahilly, Gray and Gardner, 1957
Cavitation in elbow ...	?	22-28	6-7	Gray and Gardner, 1951
Cavitation in shoulder..	?	25	6½	Gardner and Gray, 1953
Cavitation in hand.....	?	26-30	6½-7	Gray, Gardner and O'Rahilly, 1957
Ossifying ulna	22-23	23.0-32.2	6½-7	O'Rahilly, Gray and Gardner, 1957
Ossifying distal phalanges	?	26-30	6½-7	Gray, Gardner and O'Rahilly, 1957
Ossifying scapula	?	30	7	Zawisch, 1954
Cavitation in wrist	?	30-31	7	Gray, Gardner and O'Rahilly, 1957

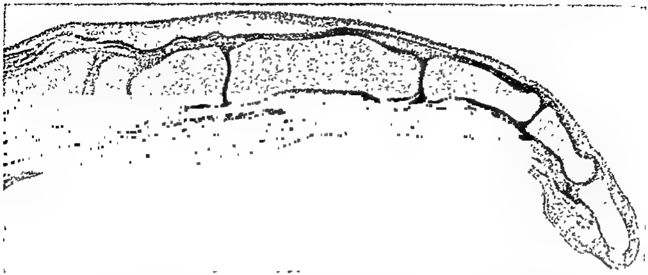


FIG. 1. Sagittal section of the third finger of the right hand of a human embryo aged 6½ weeks (26 mm.). The cartilaginous skeletal elements, from left to right, are: Radius; lunate; capitate; third metacarpal; and 3 phalanges. Ossification is beginning at the tip of the distal phalanx. (Gray, Gardner and O'Rahilly: Am. J. Anat. 101:205)

The metacarpals begin to chondrify at the same time, 5 weeks (Stages 17-18), as the carpals. During the next week (Stages 18-21) the three rows of phalanges commence to chondrify in proximodistal sequence[27] (Fig. 1).

A large number of accessory skeletal elements have been described for the hand.[24] A cartilaginous centrale is found more or less constantly in the carpus during the sixth week (17-24.5 mm. C. R.). Subsequently, it usually fuses with the cartilaginous scaphoid. A chondrifying nodule termed the triangulare is seen sometimes in the fetal carpus in close relation to the developing articular disk of the distal radio-ulnar joint.

The digital sesamoids first appear during intra-uterine life, slightly later than the other ("canonical") skeletal elements. Those of the hand may begin to chondrify as early as 7 weeks, and their distribution and frequency resemble closely those of the adult.[12]

The initial phase in the development of the synovial joints, namely, the formation of "interzones" between the various skeletal segments (Fig. 1), takes place during the last two weeks of the embryonic period proper.[12] Although a few joint cavities may be observed in the hands of some embryos, cavitation generally commences in the joints of the hand during the first two weeks of the fetal period.

It should be emphasized that the phase of initial chondrification and preliminary joint formation in the hand takes place entirely within the embryonic period proper (Fig. 1). All the "canonical" elements of the hand have begun to chondrify by 6 postovulatory weeks; therefore, the number and the arrangement of these elements are determined prior to this time. It follows that

FIG 2 (A) This photomicrograph and the 5 succeeding figures are taken from the right hand of a human fetus of approximately 12 menstrual weeks (69 mm.). This figure shows a frontal section of the fourth metacarpal. The hypertrophied cartilage cells of the shaft are evident, and a bone collar can be seen. (B) Frontal section of the second metacarpal. A periosteal bud has invaded the cartilaginous shaft through a perforation in the bone collar. (C) Frontal section of the proximal phalanx of the second finger, showing bone collar and hypertrophied cartilage. (D) Frontal section of the middle

(*Continued on facing page*)

FIG. 2 (Continued from facing page)

phalanx of the second finger, showing eccentrically placed bone and hypertrophied cartilage. (E) Horizontal section of the second metacarpal, showing multiple invasion of the bone collar and cartilage by periosteal buds. (F) Frontal section of the distal phalanx of the second finger, showing characteristic formation of bone at its tip. (Gray, Gardner and O'Rahilly: Am. J. Anat. 101:169-224)

anomalies in which the number of skeletal elements is increased arise very early in intra-uterine life, and that the causative factors must act before 6 weeks of development. Examples of such anomalies are polydactylia and ulnar dimelia.[25] It is possible that, owing to failure of a skeletal segment to continue in development, a decrease in the number of skeletal elements may arise after, as well as during, the embryonic period proper. Examples of such anomalies are hypodactylia and radial hemimelia.[25] However, on the basis of experimental observation,[31] it seems likely that the various types of hemimelia are produced at the very early embryonic phase during which the ectodermal ridge normally is active.

It has been known for many years that the time in development at which a teratogenetic agent acts is important in determining the reaction of the embryo or fetus.[12] In the chick, for example,

> we may conclude, in general, that each organ system has its own specific periods of high sensitivity. These may occur during its formation, during its rapid differentiation, during its onset of function, or in its regulation with respect to the environment or to other systems in the embryo [14]

Moreover, mortality due to disturbances of developmental processes is more frequent at certain general "critical periods" of development.[14,39]

It has been shown experimentally by many workers that a teratogenetic agent (e.g., x-rays) may cause different malformations when applied at different times during development.

> These time-specific effects are related to definite stages or events in embryonic development which might be regarded as periods of special susceptibility.[39]

In addition to time-specificity, there may also be an agent-specificity; i.e., a particular group of malformations may be associated with a particular agent, but this is not always readily apparent.[39]

The employment of mammals in experimental teratology by many workers has shown that similar teratologic processes are involved in that class of vertebrates. In a study of x-ray induced developmental abnormalities in mice,[30] for example, it has been found that the critical period during which anomalies of the feet are produced coincides with a very early phase in the development of the limbs. In terms of human embryology, this phase probably corresponds to 4 to 5 postovulatory weeks.[28] It is of interest to record that, in the experiments on mice just mentioned, the critical period for the production of overgrowth (e.g., polydactylia) was earlier than that for the inducement of reduction (e.g., hypodactylia).

PHASE OF OSSIFICATION IN THE HAND

The period during which ossification commences in the hand extends from the end of the embryonic period proper to postnatal life.

The only site in the hand where ossification is likely to occur during the embryonic period proper is at the tips of the distal phalanges (Fig. 1). Intramembranous bone formation has been found here in some embryos at 7 postovulatory weeks (Stage 23).[27] The peculiar mode of ossification of the distal phalanges (Fig. 2 F) has been described in detail.[6,33] Dixey[6] pointed out that calcification, intramembranous ossification and endochondral ossification commence at the tip of a distal phalanx instead of at the center of the shaft, as in other tubular bones. These processes then advance in only one direction, namely, proximally (Fig. 2 F). The tuberosity of the distal phalanx is formed by further development of this area of intramembranous bone formation.

During the fetal period, bone collars (Figs. 2 A, C & D) may be discerned in each of the metacarpals and the phalanges some little time (1-5 weeks) before the appearance of the periosteal buds; hence, before the centers of endochondral ossification are formed. The vascular invasions

TABLE 2. C. R. LENGTHS AND TIMES DURING WHICH BONE COLLARS AND VASCULAR INVASION OF THE SHAFT FIRST OCCUR IN THE METACARPALS AND THE PHALANGES OF THE HAND (GRAY, GARDNER & O'RAHILLY, 1957)

	BONE COLLAR		VASCULAR INVASION	
	MM.	MENSTRUAL WEEKS	MM.	MENSTRUAL WEEKS
Metacarpals 1-5	30-45	9-10	43-65	10-11
Proximal phalanges 1-5	43-50	9-10	65-83	11-13
Middle phalanges 2-4	56-73	10-12	85-110	13-15
Distal phalanges 1-5	26-43	8-10	60-110	11-15

(Figs. 2 B & E) that herald the approach of the ossification centers (Table 2) appear in the metacarpals and the phalanges between 9 and 15 menstrual weeks.[12] However, the center for the middle phalanx of the little finger may be delayed until full term.

Ossification usually does not begin in the carpus until after birth (Table 3). However, the capitate and the hamate may show ossific centers in the newborn.[5] The individual carpals generally begin to ossify during the first 6 years,[15] with the exception of the pisiform, which commences ossification at about 10 years. Some of the carpals, particularly the lunate, the scaphoid and the pisiform, may begin at two or more loci each.

The bony epiphyses of the metacarpals and of the phalanges make their appearance during childhood, commonly during the first four postnatal years. These centers unite with the corresponding diaphyses at about the time of puberty. The detailed dates of Todd and his associates have been analyzed and summarized.[23]

The bony epiphyses generally appear at the bases of the elements, with the exception of the second to the fifth metacarpals, where they usually develop at the heads. However, additional centers may appear at the op-

TABLE 3. TIMES OF APPEARANCE OF POSTNATAL OSSIFIC CENTERS IN THE HAND. MEAN AGES IN YEARS, BASED ON PUBLISHED DATA (MAINLAND, 1945; GREULICH & PYLE, 1950)

BONE	APPEARANCE		COMPLETE RADIOGRAPHIC FUSION	
	FEMALE	MALE	FEMALE	MALE
Radius, distal end	1	1	16	18
Ulna, distal end	6-7	5-7	16	18
Capitate and hamate	by 1	by 1		
Triquetral	2	2-3		
Lunate	2-3	3-4		
Trapezium, trapezoid and scaphoid	4	4-6		
Pisiform	8-9	10-11		
[illegible]	1-2	1-2	14	17
[illegible]	1-3	1-3	14	17
Sesamoids	11	13		

posite end of an element, particularly in a metacarpal. Such centers are commonly termed *pseudo-epiphyses* but are better referred to as supernumerary or accessory epiphyses. A connecting bridge between a supernumerary epiphysis and the corresponding diaphysis is interpreted by some authors as an extension of ossification from the shaft into the cartilaginous end and by others as an expression of secondary fusion between the two independent centers.[20]

The various pathologic deviations in the ossification of the hand have been described and discussed in special works.[4]

The digital sesamoids commence to ossify during late childhood and early adolescence.[18] The lateral and the medial sesamoids at the metacarpophalangeal joint of the thumb are practically constant. Rarely, one of them may be bipartite.[17] A medial sesamoid for the little finger is usually present (77%,[17] 79%,[16] 70%[18]), and a lateral sesamoid for the index finger is frequent (56%,[17] 40%[16], 35%[18]). The remaining metacarpophalangeal sesamoids are uncommon, but hands having 10 sesamoids have been described. An interphalangeal sesamoid for the thumb is usually present (63%,[16] 74%[18]). It is of interest to note that, within a year of the discovery of x-rays, a roentgenographic survey of the digital sesamoids was published.[8]

SKELETAL MATURATION AND THE HAND

Skeletal development involves three interrelated but dissociable components: increase in size (growth), increase in maturity, and aging.[2] Skeletal maturation or osteogenesis is

> the metamorphosis of the cartilaginous and membranous skeleton of the foetus to the fully ossified bones of the adult [1]

However, skeletal status does not necessarily correspond with the height, the weight or the age.

It has been found that

> the maturative changes in the skeleton are intimately related to those of the reproductive system, which, in turn are directly responsible for most of the externally discernible changes on which the estimation of general bodily maturity is usually based.[13]

Furthermore, because it is maintained that

> the skeleton of the healthy, adequately nourished child develops as a unit, and its various parts tend to keep pace with each other in their maturation,[13]

roentgenographic examination of a limited portion of the body is believed by some workers to suffice for an estimation of the maturity of the entire skeleton. The hand is the portion examined most frequently—"as the hand grows, so grows the entire skeleton" it is sometimes stated.

The assessment of skeletal maturity is important in determining whether an individual child is skeletally advanced or retarded, and, therefore, in diagnosing endocrine and nutritional disorders. Skeletal status is expressed frequently in terms of skeletal age. This involves the comparison of roentgenograms of certain areas with standards for those areas; the skeletal age assigned is that of the standard which corresponds most closely. Detailed standards for the normal postnatal development of the hand have been published.[13]

Some workers find it useful to count the number of ossific centers visible in a region such as the hand.[29] Other investigators roentgenograph a larger area for this purpose; e.g., the entire upper and lower limbs of one side of the body.[7,35]

Another system of assessing skeletal maturity,[1,2,3] an alternative to the use of skeletal age, depends on the successive numbering of maturity indicators in a given region. These numbers or maturity points are added together to constitute a total score, which is an index of the skeletal maturity of the region shown in a given roentgenogram. By the use of this method, skeletal maturity is measured on a scale of its own and not directly in terms of chronologic age. Details

...chnic, as applied to the early ossi-
...of the hand have been published,[1]
...later phases of development are in
...e of preparation.[3]

SUMMARY

...count of the skeletal development of
... is presented, the prenatal findings
...sed on the research of the present
... the postnatal findings being sum-
...from the literature.

...pper limb buds appear at 4 post-
... weeks (Stage 12). A few days
...important ectodermal ridge (Stage
...a skeletomuscular condensation are
...ge 15).

...rious skeletal elements of the hand
...guished as condensed mesenchyme
...vulatory weeks (Stage 17). Chon-
... takes place in a definite sequence
... sixth week (Stages 17-21).

...phasized that the number and the
...nt of the "canonical" skeletal ele-
...the hand are determined prior to
...latory weeks of *intra-uterine life.*
...amoid of the hand may begin to
...as early as 7 postovulatory weeks.
...ribution and frequency resemble
...se of the adult.

... of the distal phalanges may begin
...s early as 7 postovulatory weeks
...). The vascular invasions that
... appearance of the endochrondral
...ters are found in the metacarpals
...tal, the proximal and the middle
phalanges generally between 10 and 16 menstrual weeks. However, bone collars can be detected 1 to 5 weeks earlier.

Ossification takes place in the carpus in a more or less definite sequence during childhood. The metacarpal and the phalangeal epiphyseal centers appear during early childhood Roentgenographic fusion of these last-mentioned centers occurs about the time of puberty. Roentgenograms of the hand are used frequently for the assessment of skeletal maturation, the chief methods for which are mentioned.

REFERENCES

1. Acheson, R. M.: A method of assessing skeletal maturity from radiographs, J. Anat. 88:498-508, 1954.
2. ———: The Oxford method of assessing skeletal maturity *in* Clinical Orthopaedics No. 10, pp. 19-39, Philadelphia, Lippincott, 1957.
3. ———: Some observations on recent research in human growth, with a note on its assessment in clinical practice, Irish J. M. Sc., pp. 29-36, Jan., 1958.
4. Brailsford, J. F.: The Radiology of Bones and Joints, ed. 5, London, Churchill, 1953.
5. Christie, A.: Prevalence and distribution of ossification centers in the newborn infant, Am. J. Dis. Child. 77:355-361, 1949.
6. Dixey, F. A.: On the ossification of the terminal phalanges of the digits, Proc. Roy. Soc., London 31:63-71, 1881.
7. Elgenmark, O.: The normal development of the ossific centers during infancy and childhood, Acta paediat. (Suppl. 1) 33:1-79, 1946.
8. Fawcett, E.: On the sesamoid bones of the hand: a skiagraphic confirmation of the work done by Pfitzner, J. Anat. Physiol. 31:157-161, 1896.
9. Fenart, R.: Développement du plexus brachial chez l'embryon humain, thesis, Faculté de Médecine de Paris, 1956.
10. Gardner, E., and Gray, D. J.: Prenatal development of the human shoulder and acromioclavicular joints, Am. J. Anat. 92:219-276, 1953.
11. Gray, D. J., and Gardner, E.: Prenatal development of the human elbow joint, Am. J. Anat. 88:429-470, 1951.
12. Gray, D. J., Gardner, E., O'Rahilly, R.: The prenatal development of the skeleton and joints of the human hand, Am. J. Anat. 101:169-224, 1957.
13. Greulich, W. W., and Pyle, S. I.: Radiographic Atlas of Skeletal Development of the Hand and Wrist, Stanford Univ. Press, 1950.
14. Hamilton, H. L.: Sensitive periods during development, Ann New York Acad. Sc. 55:177-187, 1952.
15. Hochstetter, F.: Über die Entwicklung der Form der menschlichen Gliedmassen, Österr. Akad. Wissen. math.-natur. Klasse Denk. 109:1-35, 1952.
16. Hubay, C. A.: Sesamoid bones of the hands and feet, Am. J. Roentgenol. 61:493-505, 1949.

17. Inge, G. A. L., and Ferguson, A. B.: Surgery of the sesamoid bones of the great toe Anatomic and clinical study, Arch. Surg. 27:466-489, 1933.
18. Joseph, J.: The sesamoid bones of the hand and the time of fusion of the epiphyses of the thumb, J. Anat. 85:230-241, 1951.
19. Kassatkin, S.: Die Sesambeine der Hand und des Fusses des Menschen, Z. Anat. Entw. 102:635-654, 1934.
20. Lachman, E.: Pseudo-epiphyses in hand and foot, Am. J. Roentgenol. 70:149-151, 1953.
21. Lewis, W. H.: The development of the arm in man, Am. J. Anat. 1:145-184, 1902.
22. McKay, D. G., Adams, E. C., Hertig, A. T., and Danziger, S.: Histochemical horizons in human embryos. II. 6 and 7 millimeter embryos — Streeter horizon XIV, Anat. Rec. 126:433-463, 1956.
23. Mainland, D.: Anatomy As a Basis for Medical and Dental Practice, Hamilton, London, 1945.
24. O'Rahilly, R.: Developmental deviations in the carpus and the tarsus *in* Clinical Orthopaedics No. 10, pp. 9-18, Philadelphia, Lippincott, 1957.
25. ———: Morphological patterns in limb deficiencies and duplications, Am. J. Anat. 89:135-194, 1951.
26. O'Rahilly, R., Gardner, E., and Gray, D. J.: The ectodermal thickening and ridge in the limbs of staged human embryos, J. Embryol. Exper. Morphol. 4:254-264, 1956.
27. O'Rahilly, R., Gray, D. J., and Gardner, E: Chondrification in the hands and feet of staged human embryos, Contr. Embryol. 36:183-192, 1957.
28. Otis, E. M., and Brent, R.: Equivalent ages in mouse and human embryos, Anat. Rec. 120:33-64, 1954.
29. Reynolds, E L., and Asakawa, T.: Skeletal development in infancy. Standards for clinical use. Am. J Roentgenol. 65:403-410, 1951.
30. Russell, L. B.: X-ray induced developmental abnormalities in the mouse and their use in the analysis of embryological patterns. I. External and gross visceral changes. J. Exper. Zool. 114:545-602, 1950.
31. Saunders, J. W.: The proximo-distal sequence of origin of the parts of the chick wing and the role of the ectoderm, J. Exper. Zool. 108:363-404, 1948.
32. Saunders, J. W., Cairns, J. M., and Gasseling, M. T.: The role of the apical ridge of ectoderm in the differentiation of the morphological structure and inductive specificity of limb parts in the chick, J. Morphol. 101:57-87, 1957.
33. Schuscik, O.: Zur Verknöcherung der menschlichen Phalangen mit besonderer Berücksichtigung der Endphalanx, Anat. Anz. 51:118-129, 1918.
34. Smith, T. E., and Patt, D. I.: Organizing action of apical and pre- and postaxial ectoderm of the limb bud of the hamster as seen in intrapouch explants, Anat. Rec. 130:374, 1958.
35. Sontag, L. W., Snell, D., and Anderson, M.: Rate of appearance of ossification centers from birth to the age of five years, Am. J. Dis. Child. 58:949-956, 1939.
36. Streeter, G. L.: Developmental horizons in human embryos. Description of age group XI, 13 to 20 somites, and age group XII, 21 to 29 somites, Contr. Embryol. 30:211-245, 1942.
37. ———: A review of the histogenesis of cartilage and bone, Contr. Embryol. 33:149-167, 1949.
38. Willier, B. H.: Phases in embryonic development, J. Cell. & Comp. Physiol. 43:307-317, 1954.
39. Wilson, J. G.: Is there specificity of action in experimental teratogenesis? Pediatrics 19:755-763, 1957.
40. Zawisch, C.: Die frühe Histogenese der menschlichen Clavicula, Ztschr. mikr.-anat. Forsch. 59:187-226, 1953.
41. ———: Die Morpho- und Histogenese der menschlichen Scapula, Acta anat. 22:300-328, 1954.
42. Zwilling, E.: Teratogenesis *in* Willier, B H., Weiss, P. A., and Hamburger, V. (Eds): Analysis of Development, Sect. 14, Philadelphia, Saunders, 1955.

Le Disveloppamento del Skeleto del Mano

Summario in Interlingua

Es presentate un relation del disveloppamento del skeleto del mano. Le datos prenatal es basate super le recercas del autores. Le datos postnatal es summarisate ab le litteratura.

Le gemmas del extremitates superior appare quatro septimanas post le ovulation (stadio 12). Plure dies plus tarde, un importante cresta ectodermal (stadio 14) e un condensation skeletomuscular (stadio *15) es a vider.*

Le varie elementos skeletic del mano es distinguite como mesenchyma condensate cinque septimanas post le ovulation (stadio 17). Chondrification occurre in un ordine definite in le curso del sexte septimana post le ovulation (stadios 17 a 21).

Es signalate que le numero e le disposition del elementos "canonic" del skeleto manual es determinate ante le passage de sex septimanas post le ovulation in le vita intra-uterin.

Le sesamoides del mano pote comenciar lor chondrification jam septe septimanas post le ovulation. Lor distribution e lor frequentia es multo simile al distribution e frequentia del sesamoides de adultos.

Le punctas del phalanges distal pote comenciar lor ossification jam septe septimanas post le ovulation (stadio 23). Le invasion vascular que precede le apparition del centros ossific endochondral es trovate in le metacarpales e in le phalanges distal, proximal, e intermediari generalmente inter 10 e 16 septimanas post le ovulation. Collares ossee, del altere latere, pote esser dategite 1 a 5 septimanas plus tosto.

Le ossification in le carpo occurre durante le infantia in un ordine plus o minus definite. Le centros epiphysee metacarpal e phalangee appare tosto in le infantia. Fusion radiographic de iste centros occurre approximativemente al tempore del pubertate. Radiogrammas del mano es usate frequentement pro evalutar le maturation skeletic. Le methodos principal de iste procedimento es mentionate.

5

Studies of the Form and the Function of Some Joints of the Fingers*

R. DALE SMITH, PH.D., AND GEORGE R. HOLCOMB, PH.D.†

The joints of the fingers are not to be considered as unique cases of joint anatomy or physiology. Most of the features of the finger joints are those of diarthrodial joints in general, and the basic phenomena and relationships described here apply equally well to the other joints of the body. The studies of finger joints carried out in this laboratory are part of a more extensive program of investigation of the nature of the form and the function of human joints in general. Investigation of the finger and the hand joints was undertaken because of the misconception that the interphalangeal joints were "simple" in character and, therefore, would present the basic features of all diarthroses in a clear-cut manner. We are now convinced that there are no "simple" joints in the human body and that the humble interphalangeal joint contains as many enigmas as the more frequently described knee joint.

In the diarthrodial type of joint—and this is by far the most common and useful type in providing the overt movements of the body—the proper purpose and function depends on the interrelation of the contiguous surfaces presented by the articulating bones. The type and the amount of excursion permitted are related to the total area and also to the partition and the distribution of that area. The transmission of weight, fo[illegible] power from one member to anothe[illegible] way of the surfaces in contact betwee[illegible] Casual inspection of articulations i[illegible] that they vary considerably in the t[illegible] as well as in the relative amount of presented by each member. It is [illegible] that there are basic laws which go[illegible] total amount of articular area as we[illegible] distribution of this area between th[illegible] lating bones, and that these laws [illegible] the type of movement permitted, th[illegible] transmitted and the weight carried [illegible] pears that the angulation of the lon[illegible] the bones is also related to the amo[illegible] the distribution of the articular surfa[illegible]

Since there appeared to be no q[illegible] tive data on the amount of contact [illegible] volved in human joints, there was [illegible] a method that permitted the deter[illegible] of the total contact area in individua[illegible] and these quantitative data were c[illegible] and analyzed. The data on the joint[illegible] fingers will be discussed here.

Armed with quantitative data on t[illegible] and relative area of finger joints, a s[illegible] studies on the angulation of the b[illegible] joints was undertaken, and the res[illegible] these studies as related to the proxima[illegible] phalangeal joints will also be discusse[illegible]

MATERIALS AND METHO[illegible]

Inspection of a proximal interpha[illegible] joint after removal of the capsule reve[illegible] cartilage-covered distal end of the p[illegible]

* This investigation was supported in part by Research Grants A-1330 and A-1900 of the National Institutes of Health, Public Health Service.

† Department of Anatomy, School of Medicine, The Creighton University, Omaha, Neb.

phalanx and the proximal end of the middle phalanx. It is evident that not all of this cartilaginous area participates in the articulation within the intact joint; some of this cartilage is true articular cartilage and comes in contact with the cartilage of the contiguous bone in one position or another. Some of the cartilage is so placed that it could not, under normal conditions, be in contact with another articular cartilage; for example, the cartilage-covered dorsal surface of the proximal phalanx not articulating with the middle phalanx.

If a small quantity of casein paint is introduced through a slit in an otherwise intact joint capsule and the normal actions of the joint are simulated, there is produced an erosion pattern that bears a direct relation to the actual articulation of the cartilages within the joint. Comparison of such erosion patterns with the cartilage-covered ends of the bones demonstrates that a visible margin exists between the cartilage which articulates with that of the next bone and the cartilage which does not articulate but, rather, provides a gliding surface for the tendons and the capsule. Only the articular cartilage that actually came in contact with the contiguous articular cartilage was considered in determining the area. In each joint studied, the dividing line between the articular and the nonarticular cartilage was located by inspection and marked with ink, thereby circumscribing the true articular area of each member of the joint. In this account the term *articular area* or *articular surface* refers only to that portion of the cartilage-covered bone which was in contact with a similar cartilage on the adjoining bone composing the joint, and does not include other cartilaginous areas.

The geometric configuration of the presenting surfaces varies somewhat from joint to joint, but the most common form is that of one convex surface meeting a concave surface. The distal ends of the metacarpus are convex, as are those of the proximal and the distal phalanges. The carpometacarpal

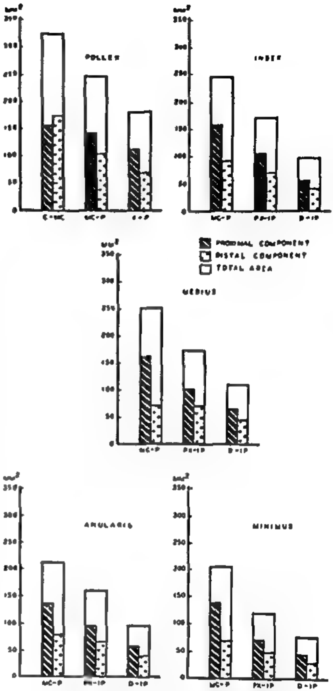


FIG. 1. The total area and the area of the individual components of a joint are shown. The joints are identified by abbreviations: C-MC = carpometacarpal joint; MC-P = metacarpophalangeal joint; PX-IP = proximal interphalangeal joints; and D-IP = distal interphalangeal joint. (Smith, R. D.: Acta anat. 32:221)

joint of the pollex presents two saddle-shaped surfaces neatly fitted together.

The areas of the articular surfaces of the distal interphalangeal and the proximal interphalangeal, metacarpophalangeal and carpometacarpal joints were measured in "nor-

TABLE 1. SUMMARY OF THE ANALYSIS OF THE MEASUREMENTS OF THE AREA OF THE ARTICULAR SURFACES OF THE JOINTS OF THE POLLEX AND THE MEDIUS

	I-P Pollex	D-IP Medius	MC-P Pollex	PX-IP Medius	C-MC Pollex	MC-P Medius
Total area in mm²	180	109	244	172	327	250
Area of concave comp. in mm²	68	44	104	71	172	90
Area of convex comp. in mm²	112	66	140	102	155	161
Concave comp., % of total	38	40	42	41	53	36
Convex comp., % of total	62	60	58	59	47	64
Size difference in %*	68	51	36	45	12	78
Index number†	60	68	74	70	111‡	56

* Convex component is percentage greater than concave.

† Index number $= \frac{\text{Area of concave component} \times 100}{\text{Area of convex component}}$

‡ Index number $= \frac{\text{Area of metacarpal I} \times 100}{\text{Area of trapezium}}$

an interphalangeal joint has 1° of freedom and needs only sufficient area for this one simple movement, the area is related to the width of the joint and the amount of unidirectional excursion. The relatively small (50%) difference between the area of the convex and the concave surfaces in the interphalangeal joints is possibly a reflection of this very simple movement. The metacarpophalangeal joint has 2° of freedom, but the area involved in one of the movements may also be used for the other movement, so that, although there are twice as many degrees of freedom, it is not necessary to have twice as much area. The metacarpophalangeal joint of the medius averages about 78 mm² more area than the proximal interphalangeal joint of the same finger. The convex component of the metacarpophalangeal joint is about 59 mm² larger than the convex component of the proximal interphalangeal joint, but the concave component of the metacarpophalangeal joint is only 19 mm² larger than is the concave component of the proximal interphalangeal joint. It appears that the convex component is providing the area for the excursion of the concave component, and, when greater excursion is to be permitted, greater area of the convex component must be provided.

THE CARPOMETACARPAL JOINT OF THE POLLEX

Since the three most distal joints of each of the five fingers were included in this study, one carpometacarpal joint—that of the pollex—was included. The joint between the trapezium and the first metacarpal is a saddle-shaped joint with varying degrees of freedom and entirely unlike any of the other joints of the hand. It is difficult to distinguish the convex and the concave members of such a joint, but, since in all the joints mentioned above the convex component was proximal and the concave distal, the position of the component also designates the nature of the surfaces. In the carpometacarpal joint of the pollex, the distal surface of the trapezium is designated as the concave, and the proximal surface of the first metacarpal as the convex, surface. It may be argued that since the convex component is always the larger of the two, the articulating surface of the metacarpal should be considered as the convex component. The areas of the two components differ so slightly that the inter-

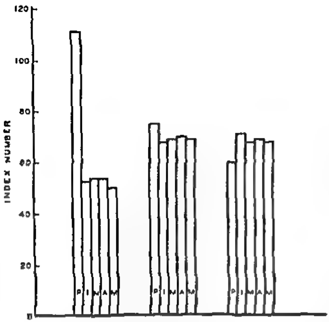


FIG. 2. Index numbers of individual joints of fingers. The joints are arranged from left to right as they occur from proximal to distal, i.e., metacarpophalangeal (carpometacarpal of the pollex), proximal interphalangeal (metacarpophalangeal of the pollex), distal interphalangeal. P = pollex; I = index, M = medius; A = anularis; M = minimus. (After Smith, R. D.: Acta anat. 32:224)

pretation of the analysis of the joint would be little different either way.

The total area of the carpometacarpal joint of the pollex averaged 327 mm², of which the first metacarpal carried 172 mm² and the trapezium 155 mm². The total area is divided almost equally between the two components, and the percentages are 53 per cent and 47 per cent for the metacarpal and the trapezium, respectively, with a percentage difference of 12. The nearly equal distribution of the area between the two components in this joint is made evident by the graphic presentation of the components in Figure 1. It is seen here that the two distal joints of the pollex show nothing to distinguish them from the two distal joints of any of the other fingers. The proximal joint of the pollex is larger than the proximal joint of the other fingers, but it is in the relative area of the two components and the larger proximal component that the unusual nature of this joint is indicated. The carpometacarpal joint of the pollex is certainly of a different categoric type from that of the other joints measured in this series.

INDEX NUMBERS

When an attempt is made to compare one joint with another, it becomes apparent that the ratio between the areas of the contiguous surfaces is the feature of significance. For this reason, an index number was calculated for each of the joints by multiplying the area of the concave surface by 100 and dividing this product by the area of the convex surface. This relationship between the areas of the two components, when developed as an index number, permits comparison of one joint with another without the variations in size of the bones obscuring the relationships.

The index numbers are shown graphically in Figure 2. It will be observed that the index numbers of the interphalangeal joints (*both distal and proximal*) are all about the same order of magnitude. These indexes are all close to 70, the distal interphalangeal joint of the pollex being the lowest with an index of 60. The interphalangeal joints all appear to be of the same basic type, having the same general distribution of the relative areas and probably, also, the same degrees of freedom and similar action.

The metacarpophalangeal joint of the pollex corresponds in position and in general function to the proximal interphalangeal joint of the other fingers. It does not appear that there is any other movement in this joint except flexion and extension; therefore, functionally it can be considered as playing the same role as the proximal interphalangeal joints of the other fingers. Anatomically, though, it must be classified as a metacarpophalangeal joint. The index number of this joint corroborates these speculations, and the figure 74 fits more nearly into the group of interphalangeal joints than anywhere else.

The index numbers of the metacarpophalangeal joints of the index, the medius, the

anularis and the minimus form a rather compact group and range from 50 to 57. They are all significantly smaller than the indexes of the interphalangeal joints and, therefore, indicate that there is a difference in the basic nature of these joints which is not evident from the simple consideration of the total area or its components.

It is of interest to compare the index numbers of the various joints of the pollex with those of the other fingers. The distal interphalangeal joint of the pollex, with an index of about 60, places it rather low among the interphalangeal joints. The metacarpophalangeal joint of the pollex, with an index of 74, places it rather high among the proximal interphalangeal group. The interphalangeal joint of the pollex is surely an interphalangeal joint, though perhaps it has some heretofore unsuspected characteristics. The metacarpophalangeal joint of the pollex corresponds more nearly to the proximal interphalangeal joints. Even though this correspondence is not perfect, the index number is certainly not large enough to be that of a carpometacarpal joint, and it is too large to be that of a metacarpophalangeal joint. The carpometacarpal joint of the pollex, with an index number of 111, is clearly an outsider in this collection and bears no relation to the interphalangeal or the metacarpophalangeal joints of any of the other fingers or of itself.

Other trends as exhibited by the index numbers might be noted. The indexes of the metacarpophalangeal joints of the four medial fingers are the lowest, while those of the metacarpophalangeal joint of the pollex and the interphalangeal joints of all the fingers form an intermediate group. Graphically, the indexes of the joints of the pollex form a rather straight line, with the distal joint the lowest and the proximal joint the highest (Fig. 2).

THE MECHANICAL AXES

In any discussion of the normal form and function of the finger joints, areal interrela-

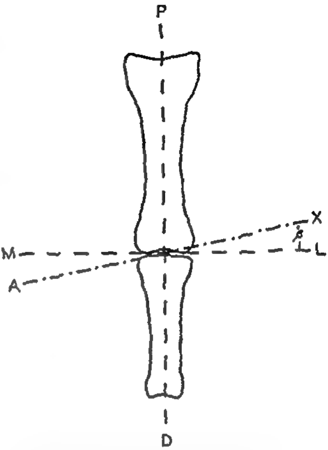


FIG. 3. Diagrammatic representation of the axes associated with the proximal interphalangeal joint. PD = proximal distal axes of the proximal and middle phalanges; ML = medial-lateral anatomic axis; AX = mechanical axis of this joint. This axis may not be parallel to ML thereby producing the angle beta.

tions must be considered, as well as the planes of the mechanical axes. Observation of the functioning normal hand will show that the fingers apparently are arranged to exhibit a certain amount of convergence upon flexion. The hand adapts itself to a sphere upon contraction. It is apparent that the fingers farthest from the meridian parallel to the long axis of the hand would have to adapt to the sphere more than those fingers close to the meridian. In other words, more of the adaptation would be seen in the index and the minimus (omitting the pollex) than in the medius and the anularis. This adaptation is probably brought about by the sum of the [illegible] of the [illegible] with the metacarpophalangeal and [illegible]

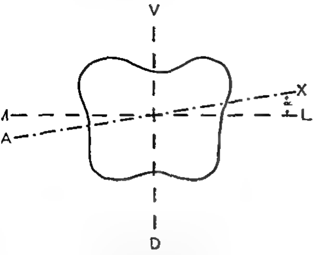


FIG. 4. Diagrammatic representation of the axes associated with the distal end of the proximal phalanx. VD = ventral-dorsal axis; ML = medial-lateral axis; AX = mechanical axis of the joint, which in this plane may also not be parallel to ML and thus produce angle alpha.

nal and the distal interphalangeal joints all contributing.

In an attempt to put this phenomenon on a quantitative basis and to evaluate the contribution of each of the joints of the fingers, measurements of the planes of the mechanical axes were made on the proximal interphalangeal joints of the index, the medius, the anularis and the minimus. Usually it can be observed that flexing the index or the minimus at the proximal interphalangeal joint prevents the distal two phalanges from lying in exactly the same plane as the proximal phalanx. There are two possible mechanisms that could bring about this result.

When the extended finger is viewed from the dorsal aspect (Fig. 3), it is evident that the proximal and the middle phalanges are in a straight line, corresponding to P-D, and that the mechanical axis of this joint would correspond more or less to the medial-lateral anatomic axis (M-L). This mechanical axis of the joint could conceivably, while remaining in the same plane as the medial-lateral axis, not be at right angles to the long axis of the finger. The axis then would assume a position similar to the line A-X in Figure 3 and produce the angle β. Such a deviation of the mechanical axis of the joint from the medial-lateral anatomic axis occurring in the coronal plane is called coronal deviation.

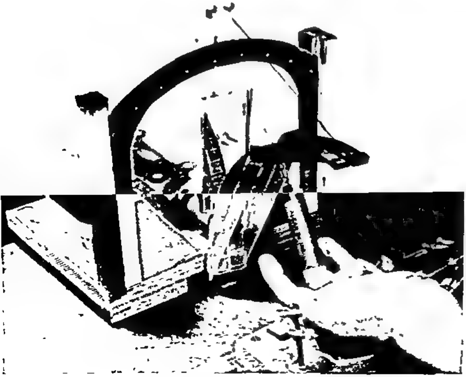


FIG. 5. Showing the apparatus used to measure the divergence occurring at the proximal interphalangeal joint.

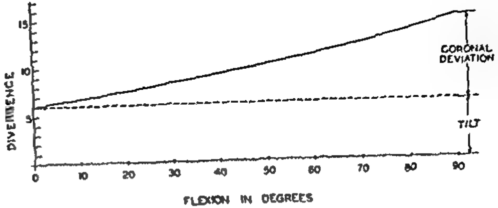


FIG. 6. Graphic representation of the curves produced in a pin joint with a *tilt* of 6° and a coronal deviation of 9°.

Divergence of the finger could be brought about by another position of the mechanical axis in relation to the anatomic axis; i.e., the axis may move in the transverse plane. Figure 4 is a diagram of the distal end of the proximal phalanx viewed from the front. The line V-D represents the ventral-dorsal axis of the finger, and the line M-L represents the medial-lateral axis of the finger. It is generally presumed that the mechanical axis of the joint in this plane is similar to the medial-lateral axis. However, it is possible that the mechanical axis of the joint does not lie in the medial-lateral anatomic axis but may be tilted in the transverse plane, as the line A-X, and thereby produce the angle α. The condition in which the axis remains in the same transverse plane but does not correspond to the medial-lateral anatomic axis is designated as tilt. Therefore, there appear to be several possibilities for the explanation of the divergence seen at the fingertip upon flexion. The mechanical axis of the joint may not be strictly parallel to the medial-lateral anatomic axis in the coronal plane (coronal deviation); the mechanical axis of the joint may not be strictly parallel to the medial-lateral axis of the joint in the transverse plane (tilt); or both phenomena may be operating simultaneously, and their effects may be additive.

MEASUREMENTS OF DEVIATION

In order to measure the coronal deviation and tilt in the fingers of the living subject, an apparatus was devised that mechanically isolated the proximal interphalangeal joint and permitted determination of the contribution of this joint to the total amount of divergence seen in the finger. The hand and the proximal phalanx were immobilized (Fig. 5), and a shotgun shell was used to splint the distal interphalangeal joint. By using the shotgun shell to immobilize the distal interphalangeal joint, the effect measured was the result of conditions at the proximal interphalangeal joint only. The distal end of the shell was fitted with a Luer slip adapter to which a 3-inch No. 16 needle was attached to serve as a pointer as it moved in a track in a quarter circle of plastic. The quarter circle of plastic was mounted on a carefully balanced shaft which also carried a device with a hairline perpendicular to the shaft and parallel to the track in the plastic. A 14-inch protractor was mounted in front of the hairline from which the amount of divergence was read in degrees. The quarter circle of plastic was marked in 10° intervals from 0° to 90°, so that the amount of flexion of the joint was evident at all times.

The geometry of the apparatus was demonstrated and verified by making a series of measurements in the apparatus with a pin-centered joint. It was found that tilt alone produced a straight line parallel to the abscissa, while coronal deviation produced a curve whose slope increased with the degree of flexion. These effects were additive (Fig. 6).

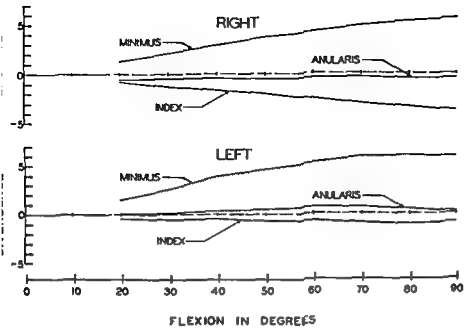


FIG. 7. The average divergence curves produced by readings made on the proximal interphalangeal joints of 40 right and 40 left hands.

RELATIVE DIVERGENCE

The proximal interphalangeal joint of the dius and the anularis showed very small ounts of divergence as compared with the ex and the minimus. In order to arrive a basis for comparison of the fingers of ferent individuals and to compensate for slight differences in orientation of hands the apparatus, all the data on divergence tained from a hand were related to the dius of that hand. Therefore, after sets readings had been taken from each of the gits, the values for the medius of that hand re subtracted from the values of the index, anularis and the minimus of the same nd. This is equivalent geometrically to ienting the hand in such a way that the and the coronal deviation of the medius exactly zero

A graph of the curves of relative divernce obtained from 40 right and 40 left nds is presented in Figure 7. The divernce is indicated by negative values when distal phalanges move in an ulnar direcon and by positive values if toward the dial side Since the divergence of the edius is always very slight, it had been duced to zero, and it appears graphically a straight line superimposed on the oscissa.

The largest amount of divergence was found in the left minimus; the smallest amount, in the anularis and the medius. The divergence occurring at the proximal interphalangeal joint of the right index finger was in an ulnar direction. The same direction of divergence was found in the left index finger but was less in amount. This small amount of divergence of the left index finger may be due to the sample's being made up of only right-handed individuals. If divergence at the proximal interphalangeal joint is associated with handedness, then one would expect to find a greater divergence in this joint in the left index finger of left-handed individuals.

The divergence occurring at the proximal interphalangeal joint of the anularis was extremely slight and moved ulnarward in the right hand and radialward in the left hand. As was pointed out earlier, this finger does not differ appreciably from the medius.

The minimus of the right hand exhibited a greater amount of divergence than any of the other fingers of the right hand, and the minimus of the left hand exhibited a greater amount of divergence than any of the other fingers of the left hand. This divergence in both hands was in a positive direction; that is, toward the radial side of the hand.

TABLE 2. MEAN VALUES OF CORONAL DEVIATION AND TILT AS MEASURED AT THE PROXIMAL INTERPHALANGEAL JOINTS OF THE INDEX, THE ANNULARIS AND THE MEDIUS

	Index		*Annularis*		*Minimus*	
	R	L	R	L	R	L
Tilt	−.22	−.20	−.48	−.21	+.94	+1.8
Coronal deviation	−3.5	−.50	0	0	+4.7	+4.2

Analysis of the divergence (Table 2) indicates that all the values for tilt are extremely small and fall within the error of the technic and the type of apparatus used. Therefore, the major factor in divergence is coronal deviation.

Part of the convergence seen in the flexed fingers is due to coronal deviation at the proximal interphalangeal joints. The proximal interphalangeal joints of the middle finger (and also the anularis) make little contribution to this convergence. The index shows some convergence, and the minimus produced the greatest measurable amount. Analysis of the movement showed that tilt was very slight while coronal deviation was responsible for the measurable convergence. The divergence was greater in the right index finger than in the left and is perhaps related to handedness.

The divergence of the right index finger was due to the −3.5° coronal deviation and not to the small (−.22°) amount of tilt. There was no measurable amount of coronal deviation and a very small amount of tilt in the annularis of both hands. The divergence at the proximal interphalangeal joint of the minimus of both hands was caused by the large amount of coronal deviation, which was greater in amount than for any of the other fingers measured.

From these data it is evident that tilt, as illustrated in Figure 4, plays a relatively minor role in the divergence seen at the proximal interphalangeal joint, and that the mechanical axis of the joint is very nearly parallel to the medial-lateral axis of the finger in the horizontal plane. In the coronal plane the data indicate that the axis of the joint is not parallel to the medial-lateral axis of the finger, and that this circumstance is responsible for the divergence at the proximal interphalangeal joint.

CONCLUSIONS AND SUMMARY

The total articular area available in a diarthrodial joint is somewhat related to the size of the bones entering into the articulation. In these hand joints the proximal component is convex and has more area than the distal concave component. An exception to this is seen in the carpometacarpal joint of the pollex. The relationship between the areas of these components of a joint may be expressed as an index number. The index numbers indicate that the proximal and the distal interphalangeal joints are very similar in nature, while the metacarpophalangeal joint is a somewhat different type of joint. The indexes of the pollex show that the metacarpophalangeal joint of this digit is not significantly different from the interphalangeal joints of the other fingers, and in this respect the pollex may be considered as possessing two interphalangeal joints, hence three phalanges. Clearly, the carpometacarpal joint of the pollex is entirely different from the metacarpophalangeal and the interphalangeal joints, not only in total area but on the basis of the smaller area of the proximal component when compared with the distal. This is clearly shown by the singular index number of this joint.

Studios in re le Forma e Function de Alicun Articulationes Digital

Summario in Interlingua

Le area del superficies articulatori de un varietate de articulationes manual e digital esseva mesurate. Le area articulatori del superficie proximal de iste articulationes esseva generalmente plus grande que illo del superficie distal. Le articulationes interphalangee proximal e distal del quatro digitos e le articulationes interphalangee e metacarpophalangee del pollice habeva indices de circa 69. Le articulationes metacarpophalangee del quatro digitos habeva indices de circa 53. Le articulation carpometacarpal del pollice habeva un indice de 111, lo que indica un completemente differente relation.

Esseva construite un apparato pro registrar le divergentia del articulationes proximal e interphalangee in flexion. Iste divergentia esseva analysate in comparation con le digito medie, proque le divergentia in le digito medie se revelava como negligibile. Le registrate divergentia esseva interpretate como resultato del facto que le axe mechanic non esseva parallel al axe mediolateral in le plano coronal (deviation coronal) o del facto que le axe mechanic non esseva parallel al axe medio-lateral in le plano horizontal.

Le resultatos del studio indica que le divergentia al articulation interphalangee proximal resulta quasi totalmente del deviation coronal. Le articulation interphalangee proximal del digito anular in le mano dextere e in le mano sinistre monstrava nulle deviation; in le caso del digito indice ille deviation esseva al minus mesurabile; sed in le caso del digito minime illo monstrava le plus grande valores. Leve differentias inter le deviation coronal in le caso del mano dextere e del mano sinistre esseva trovate solmente pro le digito indice.

6

Principles in Covering Surface Defects of the Hand

S. Baron Hardy, M.D., F.A.C.S.*

The purpose of this chapter is to call attention to principles involved in the surface covering of the hand. Although replacement of surface covering may be only a part of the over-all reconstructive problem in the repair of the hand, it is *the most important* single factor, since all subsequent deeper repair is dependent on good surface covering. Because of the extreme importance of the hand to the individual in his daily activities, sound surgical principles of reparative surgery must be followed closely in its repair to ensure best results. Attention is directed first to general considerations in the covering of the normal hand. The palmar covering is thick and fixed, able to withstand shock and friction. It contracts and folds on itself, becoming approximately 1½ inches shorter when a fist is made. The dorsal skin is thin, elastic and freely movable, becoming stretched considerably in making a fist.

Lines of tension, or Langer's lines, coinciding with those that Bunnell calls "lines of push and pull," as well as the flexion creases, have a certain definite relationship in hand surgery. With few exceptions, margins of grafts should not be placed along the axes of Langer's lines, as this leads to thickened scars because of the irritation produced by motion. Instead, margins of grafts in general should be placed to follow the flexion creases and should extend to the mid-lateral lines of the fingers; that is, they should overlie the "neutral zones" as much as possible. Margins of grafts should not overlie tendons, vessels or nerves to prevent adhesions. Nor should they be placed where deeper repair is contemplated; they should be allowed to extend beyond this field. If it becomes necessary to cross a flexion crease, this should be done in a curved or a zigzag manner.

To summarize, preliminary principles to be kept in mind when planning surface covering of the hands are:

1. Visualize the extreme opposite position of the normal hand so as to make allowance for adequate covering; that is, if a contracture is present over the dorsum, consider the hand in the closed-fist position when planning skin for covering.

2. Consider the functional differences in palmar and dorsal skin.

3. Place margins of grafts with reference to flexion creases and lines of tension and, for the most part, have them parallel closely the direction of well-planned surgical incisions.

A few incisions in the hand are indicated by the dotted lines in Figure 1, *top*, while Figure 1, *bottom*, shows the actual incisions made in a hand in doing an exploration for lacerated tendon and its repair.

Methods to be discussed in covering surface defects are (1) the utilization of exist-

* Professor of plastic and maxillofacial surgery, Baylor University College of Medicine, Houston, Texas.

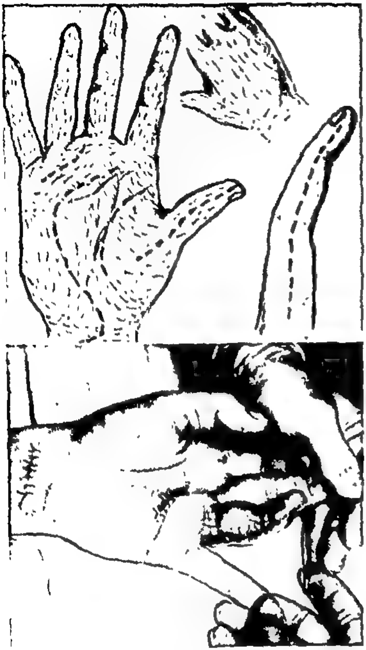


FIG. 1. (*Top*) Langer's lines and a few surgical incisions indicated by dotted lines. (*Bottom*) Sutured incisions made in the hand for a lacerated tendon exploration and its repair.

ing coverage; (2) free grafts; (3) pedicle grafts; and (4) a combination of these methods.

In certain cases, where contractures are superficial and involve only skin, many times a simple transplantation of skin using Z-plasty technic will release the contracture without the use of grafts Figure 2 illustrates a contracture of the palmar aspect of the index finger in which the contracture is superficial and has been corrected by Z-plasty. Here (*top*) the contracture is diagrammed and correction is shown using double Z, as illustrated by Bunnell and (*center*) is the transposition of flaps in Z-plasty principle.

In other cases it may be necessary to add additional skin as a free graft to supplement the Z-plasty, as in the case of the palmar-surface burn of the hand shown in Figure 3.

This method also applies to certain congenital anomalies of the hand, as syndactylism, where a combination of interdigitating flaps with the addition of free grafts is used. Figure 4 shows complete webbing between the middle and the ring fingers of the left hand which has been corrected by using interdigitating flaps to cover the fingers and

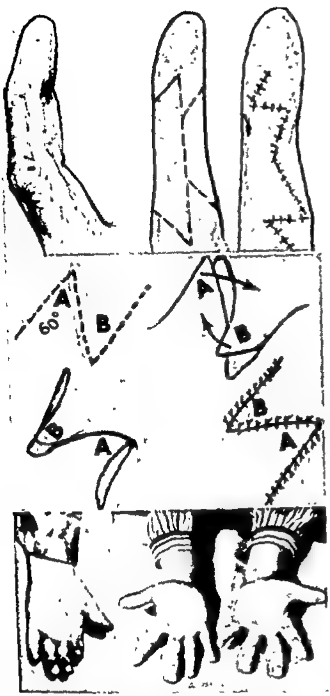


FIG. 2 (*Top*) Diagram of superficial contracture of finger. (*Center*) Diagram of Z-plasty showing procedure of transposition of flaps. (*Bottom*) Case corrected using Z-plasty technic.

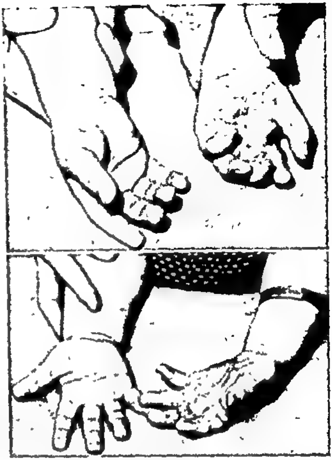


FIG. 3. (*Top*) Palmar surface burn that has been covered with full-thickness skin graft. A contracture on the thumb side is present. (*Bottom*) Contracture has been released, using Z-plasty technic.

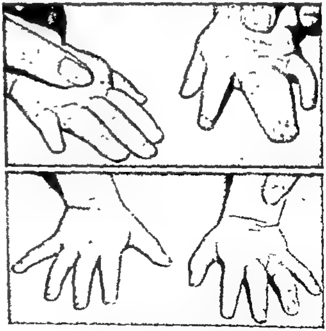


FIG 4. (*Top*) Preoperative view. (*Bottom*) Early postoperative view of syndactylism corrected by the use of interdigitating flaps and free grafts.

the webbed space, with the addition of split-thickness skin grafts to cover the denuded area at the base of each finger on the webbed side.

Free grafts are described as (1) full thickness and (2) split thickness. Free grafts are indicated in cases of loss of skin, as in skin avulsions and burns of the hand, and in

extensive superficial scarring from burns, etc., where a suitable base with a sufficient blood supply is present. In general, it can be said that the thickest graft consistent with safety is the one to be used, always bearing in mind that the *thinner* the graft the *better* the "take" but the more contracture and pigmentation and the less protection to deep structures. Therefore, from the standpoint of function the thicker graft is better.

As a rule, better results are obtained with the use of full-thickness skin grafts over the palmar surface of the hand. Occasionally, in the correction of a Dupuytren contrac-

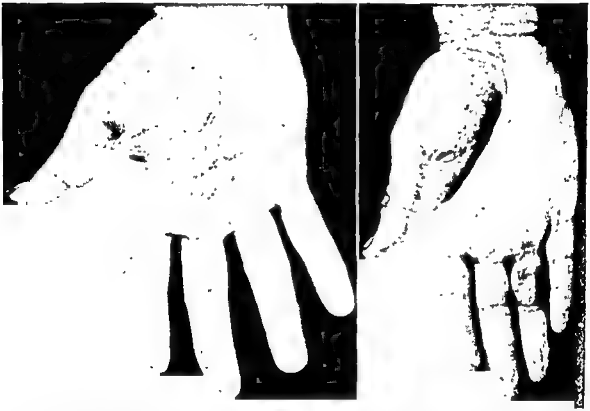


FIG. 5. (*Left*) Repair of Dupuytren's contracture using full-thickness skin graft in palm of hand (*Right*) Full-thickness skin graft on the proximal phalanx of the palmar aspect of the ring finger after excision of tumor in this area.

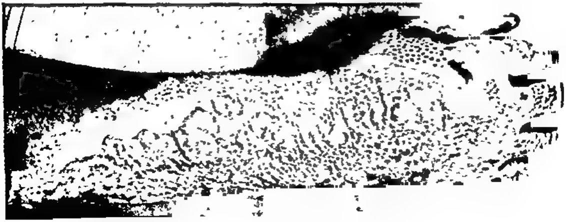


FIG 6. Deep burns of the hand and the forearm applicable to early excision and skin-grafting.

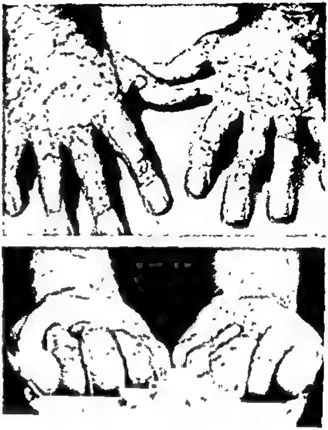
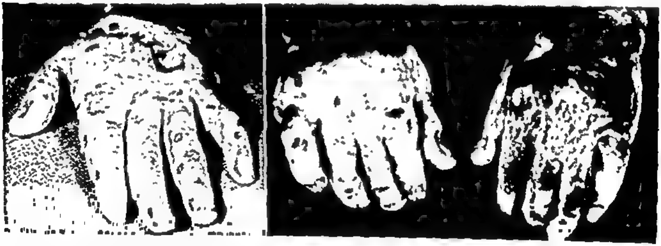


FIG. 7. (*Top*) Case in which grafting of only granulating areas was done. (*Bottom*) Blanching of skin about knuckles in making a fist indicates tightness of skin.

ture, the addition of a graft is necessary to close the wound. A full-thickness skin graft supplies the best material for this purpose, as Figure 5, *left*, reveals. In Figure 5, *right*, a *full-thickness skin graft has been applied* to the ring finger after the excision of a tumor on the palmar aspect of the proximal phalanx.

Perhaps the widest application in the use of the *split*-thickness grafts is in skin avulsions and burns of the hand where the split-thickness grafts are *used either as primary* grafting or to replace burn scars. In either case, with the loss of covering (that is, in skin avulsions and acute burns), it is highly important to get early coverage to prevent



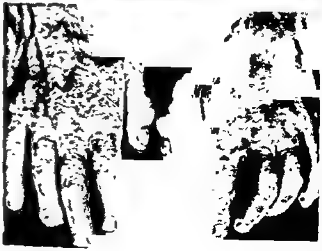


FIG. 8. Cases showing thick, unyielding burn scars of the dorsum of the hand.

bacterial invasion with resultant fibrosis and stiffening of the hand. When at all possible, in cases of deep burns of the hand, early excision of the involved area and skin-grafting should be done. Figure 6 illustrates case where this is applicable

In cases where the burn is distributed irregularly over the hand with islands of

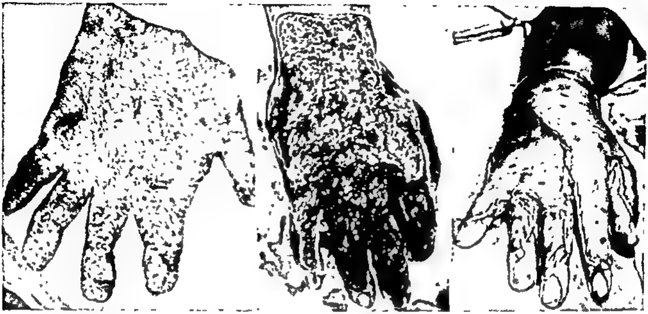


FIG. 9. (*Left*) Scar dissected off in single piece. (*Center*) Good vascular bed. (*Right*) Graft sutured into position.

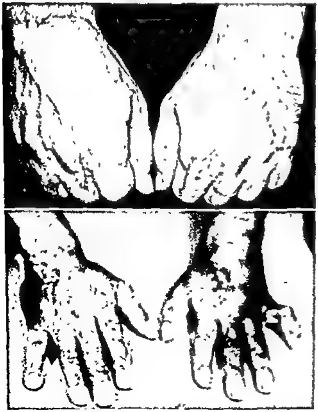


FIG 10 Postoperative views of skin grafts applied to the dorsum of the hand. (Upper illustration from Hardy, S. B.: Am J. Surg 72:357)

epithelium present, complicated with extensive body burns, one may compromise with early grafting of only the granulating areas, with the idea in mind of re-evaluating the surface covering after healing and then planning definitive treatment later. This is illustrated in Figure 7. This patient had extensive burns of the body as well as of the hands. Early coverage of the granulating areas was done. After healing, it was obvious that the skin on his hands was too tight. In making a fist, marked blanching of the skin was noted over the knuckles and the metacarpal phalangeal joint areas; definitive grafting would be necessary.

Also, in cases where the burn scar is extensive, thick and unyielding, and prevents flexion of the hand, it is necessary to dissect the scar away completely down to a good vascular base. Figure 8 illustrates three such cases. In one of these (*top, right*), the burn scar was approximately ½-inch thick in some areas. In such cases, the scar acts as an unyielding shell and limits markedly the motion of the fingers.

The procedure is indicated in Figure 9. At *left*, the scar is dissected off in a glove-like fashion, extending to the wrist, down to the base of the fingernails, over to the mid-lateral lines of the fingers and down to a good vascular bed, as shown at *center*. At *right*

is the final repair with grafts sutured into position. A pressure dressing is applied to the hand with the fingers flexed to ensure maximum length of the graft.

It is important that the grafts come to the mid-lateral lines of the fingers, that the webbed spaces be well deepened and that darts of skin in adequate amounts be sutured into the deepened webbed spaces, otherwise contractures will develop here as well as in the fingers. In the case of the dorsum of the hand, the graft must be of sufficient length to allow full flexion of the fingers (Fig. 10).

Pedicle grafts offer the best type of coverage to withstand trauma and pressure incident to the rough use of the hand; they furnish a bed under which tendons move and also make possible the preservation of length of any traumatic stump, which is so useful in the pinch-and-grasp functions of the hand.

The hand is a tactile organ, and sensation is as important as function, so that, wherever possible and especially where small pedicles are indicated, local pedicle grafts preserving sensation should be shifted into the defect and the bed of the pedicle grafted. Of course, this is more important in the palmar surface of the hand and the fingers.

In general planning, pedicle grafts should be formed approximately one third larger than the defect to be covered to allow for shrinkage of the pedicle after it is dissected up, for enlargement of the recipient area after release of the contracting scar or for freshening of the margin of the wound in acute injury. A pedicle graft located on the abdomen is comfortable to the patient with the base of the pedicle directed upward where the volar surface is concerned, and downward where the dorsal surface is to be covered. Pedicle grafts may be applied directly to the defect in one stage where it is possible to secure a wide base, or intermediate flaps—delayed flaps—may be used. Pedicles can be sutured accurately into position so that good primary healing can be obtained at the suture line, so necessary for good end-results.

FIG. 11. (*Top*) Application of pedicle graft by open method. (*Bottom*) Application of tubed pedicle to the hand. (Lower illustration from Hardy, S. B.: Am. J. Surg. 72:358)

The forearm and the hand can be splinted against the abdomen for fixation in proper position so that undue tension and torsion on the base of the pedicle are eliminated.

Pressure dressing to the pedicle must be maintained to avoid postoperative hematoma and seepage under the pedicle with resultant loss. If necessary, the hand can be splinted to maintain the hand and the fingers in proper position while the pedicle is obtaining attachment.

After about 3 weeks the pedicle can be divided and the final pedicle attachment made. In cases of small pedicles, the donor site, for the most part, can be closed primarily, but the beds of larger pedicles require skin-grafting.

The most common errors in pedicle application are the application of too small a pedicle or the use of one too bulky.

Two types of pedicles may be used: open pedicles or tubed pedicles. Figure 11, *top*, shows the application of a pedicle graft by

the open method; Figure 11, bottom, the application of a tubed pedicle to the hand.

The advantages of the open flap are that many times large areas can be covered in one stage by direct application. In acute injuries, where it is so necessary to cover large raw areas immediately, this usually is *the method of choice.* *For small defects of* the fingers, including traumatic amputation of the fingertips, cross-finger pedicles may be used.

The advantages of the tubed pedicle are that it is more aseptic, and the possibility *of infection's passing along the lymphatics* of the pedicle into the hand and producing stiffening is eliminated. Perhaps more freedom is possible with the tubed pedicle, and application in difficult places might be easier. Small tubes can be constructed in one stage, but large-tubed pedicles, of course, require stages to form, and more *meticulous care must be taken in their* formative stages.

The indications for the use of pedicle grafts are:

1. To replace skin and subcutaneous tissue loss to protect deeper structures (acute injuries). It is true that other structures may be damaged in severe crushing injuries and would demand immediate attention along with covering the wound or later repair, but our concern here is with surface covering. In acute injuries of this kind, the important principle is to get the wound closed. In a few exceptions, this might not be the wise thing to do, as in highly contaminated wounds, etc.

This covering may be accomplished

(a) by utilizing the remaining surface covering which is viable (Fig. 12, *top*). This case was one of a badly mangled hand in which most of the palmar skin was used to cover the stump.

(b) by application of a direct pedicle. Figure 12, *bottom,* is an example of an acute injury of the ulnar side of the hand with loss of the little finger. Figure 13 is the case of an acute injury of the hand with loss of the little and the ring fingers, and the tendons of the palm exposed. Figure 14 G shows a direct abdominal pedicle to cover the amputation stump of exposed bone of the middle, the ring and the little fingers.

(c) by a combination of a direct pedicle and a free graft.

2. To replace scarring involving skin and deep tissues (Fig. 14).

FIG. 12. (*Top, left & right*) This case was one of a badly mangled hand in which most of the palmar skin was used to cover the stump. (*Bottom*) Case of acute injury of the ulnar side of the hand with loss of the little finger.

FIG. 13. (*Top*) Preoperative view of injured hand with loss of little and ring fingers, tendons of the palm exposed. (*Center*) View after débridement, ready for pedicle attachment. (*Bottom*) Early postoperative view showing pedicle in place before pedicle revision.

3. To cover bones, tendons and joints (Fig. 14).

4. To replace constricting and intrinsic scars and improve circulation to the hand in general, preparatory to deeper reconstructive surgery (Fig. 15).

5. To replace deep ulcerating wounds due to various etiologies (Fig. 16). This was a case of a squamous cell carcinoma of the dorsum of the hand that had been treated with radium applications. There was present a large indurated ulcer that required wide excision, including the excision of the extensor tendon to the middle finger and the underlying periosteum and adjacent bone. It was repaired by using a direct abdominal flap in closure.

CONCLUSIONS

Principles involved in the surface covering of the hand, utilizing various types of coverage, together with photographs, are discussed.

It should be emphasized again that in many instances the surface covering is only a part of the reconstructive problem in the

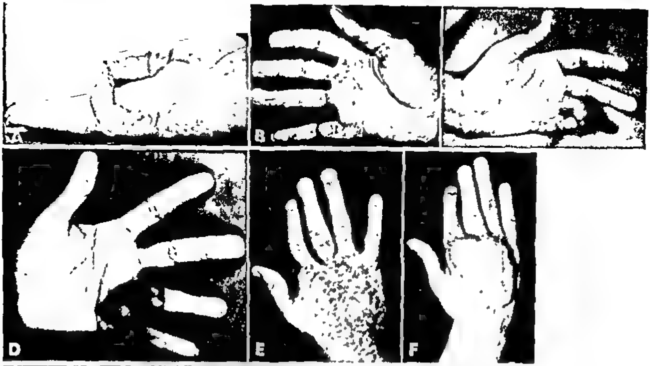


FIG. 14. (A-D) Deep contractures involving tendons with application of pedicle graft previous to tendon reconstruction. (E & F) Deep scars of the dorsum with coverage by pedicle graft. (G) Application of abdominal pedicle to cover exposed bone and preserve the length of the amputation stump in acute traumatic injury of the middle, the ring and the little fingers. (A & B from Hardy, S B.: Am. J. Surg. 72:358 & 359)

FIG. 15. *From left to right.* (1) Postoperative view of an intrinsic scar. (2) Preoperative view of an intrinsic scar. (3-5) Deep intrinsic scarring correctable by pedicle graft.

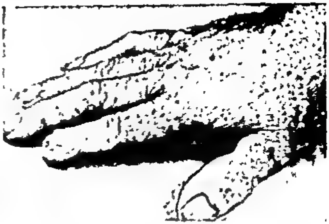


FIG. 16. (*Left*) Case of squamous cell carcinoma of the dorsum of the hand that had been treated by radium therapy. (*Right*) Postoperative view after wide excision and repair using abdominal pedicle.

repair of the hand, but, certainly, unless properly applied, later deeper reconstruction is more difficult or entirely impossible.

BIBLIOGRAPHY

Bell, J. L., Mason, M. L., and Allen, Harvey: Management of acute crushing injuries of the hand and forearm over a five-year period (1948-1952), Am. J. Surg. 87:370-378, 1954.

Blocker, T. G., Jr., and Mithoefer, J.: Pattern flap, Plast. & Reconstruct. Surg. 5:163-167, 1950.

Brown, J. B.: Closure of surface defects with free skin grafts and with pedicle flaps, Surg., Gynec. & Obst. 84:862-865, 1947.

Brown, J. B., *et al.*. Direct flap repair of defects of the arm and hand; preparation of gunshot wounds for repair of nerves, bones, and tendons, Ann. Surg. 122:706-715, 1945.

Bruner, J. M.: Incisions for plastic and reconstructive (non-septic) surgery of the hand, Brit J. Plast. Surg. 4:48-55, 1951.

———: Problems of post-operative position and motion in surgery of the hand, J. Bone & Joint Surg. 35A:355-366, 1953

Bunnell, S.: Plastic problems in the hand, Plast. & Reconstruct. Surg. 1:265-270, 1946.

———: Surgery of the Hand, ed. 3, Philadelphia, Lippincott, 1956.

Clarkson, P.: The care of open injuries of the hand and fingers with special reference to the treatment of traumatic amputations, J. Bone & Joint Surg 37A:521-526, 1955.

Dupertuis, S. M.: Skin grafts in reconstructive surgery of the hand, Plast. & Reconstruct. Surg. 12:167-175, 1953.

Edgerton, M. T.: Immediate reconstruction of the injured hand, Surgery 36:329-343, 1954.

Evans, E. M.: Treatment of major injuries of the hand, Brit. J. Plast. Surg. 2:150-174, 1949.

Flynn, J. E.: Problems with trauma to the hand, J. Bone & Joint Surg. 35A:132-140, 1953.

Hardy, S. B.: Rehabilitation of the injured hand, Am. J. Surg. 72:352-362, 1946.

Hill, E. J.: Reconstuctive surgery of the hand, Plast. & Reconstruct. Surg. 11:354-365, 1953.

Kitlowski, E. A.: Preservation of tendon function by the use of skin flaps, Am. J. Surg. 51:653-661, 1941.

Koch, S. L.: Transplantation of skin and subcutaneous tissue to the hand, Surg., Gynec. & Obst. 72:157-177, 1941.

McCormack, R. M.: Final repair of severely injured hand, Plast. & Reconstruct. Surg. 3: 687-693, 1948.

Mason, M. L., and Bell, J. L.: The treatment of open injuries to the hand, S. Clin. North America 36:1337-1361, 1956.

Posch, J. L.: Injuries of the hand, S. Clin. North America 33:1081-1094, 1953.

———: Secondary tenorrhaphies and tendon grafts in injuries to the hand, Am. J. Surg. 85:306-318, 1953.

Robins, R. H. C.: The primary reconstruction of the injured hand, Ann. Roy. Coll. Surgeons England 14:355-370, 1954.

Shaw, D. T.: Open abdominal flaps for repair of surface defects of the upper extremity, S.

Clin. North America 24:293-308, 1944.
Webster, G. V.: Choice of pedicle flaps for plastic and reconstructive surgery, S. Clin. North America 24:1472-1482, 1944.
Webster, G. V., and Rowland, W. D.: Skin grafting the burned dorsum of the hand, Ann. Surg. 124:449-462, 1946.
Webster, J. P.: Thoraco-epigastric tubed pedicles, S. Clin. North America 17:145-183, 1937.

Principios pro le Effectuation de un Copertura de Defectos Superficial del Mano

Summario in Interlingua

Es discutite le principios que governa le effectuation de un copertura de defectos superficial del mano. Photographias illustrative accompania le discussion.

In planar un copertura superficial del mano on debe (1) visualisar le mano normal in extreme positiones opposite e prender in consideration un tolerantia adequate, (2) prestar attention al differentias functional del pelle palmar e del pelle dorsal, e (3) placiar le margines de graffos in relation a rugas de flexion e lineas de tension, generalmente parallel al direction de ben-considerate incisiones chirurgic.

Es discutite le methodos usate in coperir defectos superficial del mano, incluse le indicationes de lor empleo e le technicas de lor application. Le punctos coperite per iste parte del discussion es (1) le utilisation del copertura residue, (2) le uso de graffos libere, (3) le uso de graffos pediculate, e (4) le utilisation de plures de iste methodos in combination.

Graffos libere, de spissitate complete o de spissitate findite, es indicate in casos de perdita de pelle—per exemplo in avulsion o arditura cutanee—e de extense cicatrisation post arditura o altere causas, quandocunque un base adequate es presente con un provision sufficiente de sanguine.

Graffos pediculate offere le melior typo de copertura in expectation de trauma e pression como resultato de rude usos del mano. Illos forni un cossino sub le qual le tendines pote mover se e rende possibile le preservation del longor de truncos residue de amputation, lo que es multo utile in le execution del functiones de prehension e pinceation del mano.

Duo typos de graffo pediculate pote esser usate. Le un es le pediculo *aperte*. Illo permitte le copertura de areas extense in un sol manovra per application directe e es specialmente utile in casos de vulneration acute quando le copertura de grande areas exponite es un objectivo de urgentia immediate. Le secunde es le pediculo *tubate*. Illo es considerate como plus aseptic e offere minus extense possibilitates de infection al longo del vasos lymphatic in le pediculo e in le mano con le effecto resultante de fibrosis e rigiditate.

Es discutite le principios que debe governar le planar e le cura post-operatori de graffos pediculate.

Es sublineate le facto que le copertura superficial es frequentemente non plus que un del partes del problema de reconstruction de un mano, sed si iste parte non es executate appropriatemente, un reconstruction plus profunde pote devenir necessari plus tarde, quando illo es plus difficile o forsan completemente impossibile.

7

Reconstructive Surgery and the Immediate Care of the Severely Injured Hand

ROBERT M. MCCORMACK, M.D.*

In all areas of the body, but particularly in the hand, it is becoming more obvious that the term *reconstructive surgery* is merely a relative one. Previously, most physicians considered the term *reconstructive surgery* to be almost identical with secondary surgery of severely deformed parts, either congenital or acquired. The entire emphasis in the last 15 years has been to perform optimum surgery for maximum functional benefit at the earliest possible time, including, of course, surgery on the day that the deformity was acquired.

In the hand the application of this concept of reconstructive surgery is of paramount importance because the final function of this complex anatomic part is so directly proportionate to the immediate surgical care. There are many reasons for this conclusion. Basically, it concerns the complex anatomy and the fact that this anatomic area will not stand multiple surgical insults without irreparable damage due to deep cicatrix. Thus we again come to the concept of hand surgery as an area of special interest to various surgeons so well expressed by Dr. Bunnell.† He was convinced that

> the surgeon responsible for the hand should control the composite situation unhampered by anatomical limitations so that he might approach the problem from a functional standpoint. The hand surgeon must work from the elbow down in three overlapping specialties, plastic, orthopedic and neurosurgery. The hand is so intricate in structure that if dissected in turn by three different specialists, it is likely to be wrecked beyond repair. The bones, joints, muscles, tendons, and nerves, and skin are all parts of the composite mechanism of the function of the hand and they can best be repaired by the surgeon who assumes responsibility for the whole.

Yet we all realize that the graduate training program in the fields of general surgery and the specialties of surgery stress necessarily problems concerned classically with these fields. At the present time it is extremely difficult for a young surgeon to get adequate, well-balanced training to carry out these sound fundamental principles outlined by Dr. Bunnell. Therefore, at present a well-trained specialty surgeon, as well as a general surgeon, finds that his most difficult problem in treating severely injured hands concerns the tissues that he knows the least about. He does a very good job with tissue problems stressed in his particular graduate training program.

Of necessity, these facts of the present-day graduate training program enter into the analysis of a severely injured hand and reflect the final surgical judgment to a very great degree.

The first problem that comes up in the immediate care of the severely injured hand involving multiple tissues is one of judgment rather than of technic; that is, the problem

* The University of Rochester School of Medicine and Dentistry, Department of Surgery, Division of Plastic Surgery.

† Surgery in World War II—Hand Surgery, p. 20, Washington, D.C., Office of the Surgeon General, Department of the Army, 1955.

FIGURE 1 (*Caption on facing page*)

of primary reconstruction versus amputation. The only absolute indication for primary amputation in the hand is irreversible loss of blood supply to the part. The less definite indications for primary amputation vary considerably according to the training and the philosophy of the surgeon. Sound surgical judgment requires knowledge of both the benefits and the limitations of reconstructive procedures of all the tissues of the hand, not merely of those best known to the operator because of his graduate training program.

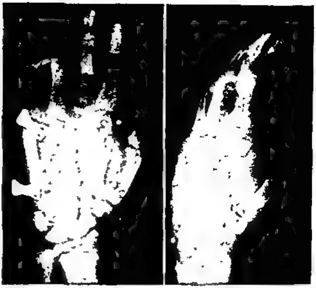
In the analysis of this initial question, as well as of further detailed points on reconstruction, it is wise to divide this analysis further into the five tissue areas: skin, nerve, bone, joint and tendon. In addition to the absolute indication of nonviability of the part, one can analyze each of the above-mentioned tissue areas separately, and, if it is anticipated that three or more of these tissues have been damaged irreversibly, it is best to amputate initially rather than to attempt reconstructive procedures. For example, the final result might be complete stiffness of joints, no motion of tendons, malunited fractures, partially anesthetic and heavily scarred surface covering. It would be better to amputate this finger. On the other hand, as experience grows with reconstructive procedures, one realizes the large number of procedures that can be done to restore any of the five tissue areas mentioned, and one usually returns to the absolute indication of irreversible loss of blood supply as the only reason for primary amputation.

In addition to the initial examination and analysis of the five tissue areas mentioned, one must outline a prognosis based on many factors, not the least of which is the mechanism of injury. This has been stressed by many, indicating the much more severe final functional prognosis for a crush injury as contrasted with a lacerating type wound. Here again individual surgical judgment, surgical experience and graduate training enter into the decision.

The most important single factor in ultimate functional prognosis of the hand is stiffness, which is reflected in the limitation of motion at the various joint levels. An accurate prediction of stiffness is extremely difficult initially, but again it reflects the mechanism of injury, the degree of damage to each of the five tissue areas, the age of the patient, motivation of the patient for a later use of the hand and, occasionally, an unanticipated postoperative complication. Obviously, all these factors are complex, and only a preliminary general prognosis is possible in the immediate analysis of the injury. However, these facts must be taken into consideration if one is attempting to carry out reconstructive surgery in the broad sense to gain maximum final function of the hand. Frequently, the "acquired deformity" of severe stiffness and resulting limitation of motion that follows a severe injury to the hand is as disabling for the final function as the specific injured area. Again, it is the attempt to minimize this "acquired deformity" that points up so well the importance of proper reconstructive surgery in the immediate care of the severely injured hand.

As pointed out so well by Furlong in his recent book, the usefulness of the hand depends on control, not on form or shape. Very logically he makes a comparison with the congenital deformity of the hand with mobile joints, lack of pain and gradual adaptation of certain functional movements by deformed parts to the acquired deformity of a previously normal hand with stiffness and pain. He points out that the congenital hand with an equal anatomic deformity so far as general form or shape is concerned fre-

FIG 1 (*On facing page*) C. E., female, age 62. (*Top, left*) Several hours after severe crush avulsion injury with disinsertion of flexor tendons and median nerve branches secondary to farm accident. (*Top, right*) Repair of digital nerves and débridement of flexor tendons. (*Bottom, left*) Function 6 months postoperatively—extension. (*Bottom, right*) Flexion view



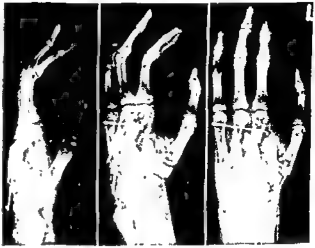
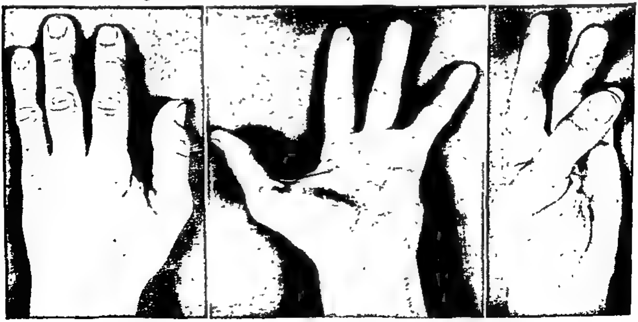


FIG. 2. J. E. (*Top, left*) Shotgun wound of hand several hours after injury. Wound of entrance on palm, wound of exit on dorsum. Preoperative dorsal view. (*Right, upper*) Preoperative roentgenograms showing extensive compound fractures, loss of portion of middle finger metacarpal head and proximal phalanx. (*Right, lower*) Postoperative roentgenogram of hand showing transfer of index finger to base of middle finger metacarpal, fixation of fractures by Kirschner wires, amputation of middle finger. (*Below*) Dorsal view 1 year after injury, postoperative volar view, postoperative opposition of thumb to little finger.



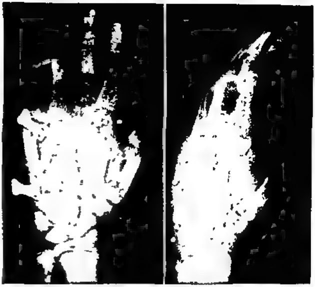
quently has a much greater function than a hand of a similar form or shape with an acquired deformity due to severe trauma.

I should like to point out some of the major problems that we have encountered in severely injured hands that involve multiple tissues.

The first such problem is the crush avulsion type of injury from severe blunt trauma involving crush avulsed skin plus disinsertion of proximal tendon ends and, occasionally, median and/or ulnar nerves as well (Fig. 1). Such severely injured deep tissues can be repaired by tendon transfers and nerve repair with a very guarded prognosis. The success of such repair depends upon the objective, rather than hopeful, evaluation of the circulation to the skin of the avulsed flap. If the circulation is judged to be inadequate in the initial analysis, it is better to sever it and replace the avulsed skin with a full-thickness graft rather than suture it back. Skin necrosis is so detrimental to the final result that proper primary skin cover should take precedence over the more dramatic disinsertion of the tendons and/or the nerves.

Another type of problem is the primary care of a gunshot wound seen early with optimum hospital conditions (Fig. 2). Such conditions include the well-known concepts of atraumatic care, meticulous débridement, immunizations, antibiotics, proper operating facilities, including anesthesia, proper postoperative dressing and physiotherapy. We feel that all these things justify much more extensive primary reconstruction of such gunshot wounds. In general, we feel that all tissues other than flexor tendons in the hands or the fingers should be actively considered for reconstruction. The three most important phases of surgical treatment in such a wound are (1) meticulous systematic débridement of all injured surfaces, which usually takes at least one half of the operating time; (2) careful alignment of fractures, usually requiring internal fixation; and (3) complete skin coverage, usually with supplementary split-thickness skin grafts and/or local rotational flaps. All three phases out-

FIGS. 3 and 4. W. F. Fig. 3. (*Top*) After thorough débridement and fixation of fractures by internal Kirschner wires prior to application of abdominal pedicle in severe cornpicker injury with multiple tissues involved. (*Center*) Preoperative roentgenogram showing multiple severe compound fractures with marked displacement. (*Bottom*) Postoperative roentgenogram showing bone graft of thumb and healing of metacarpal fractures.



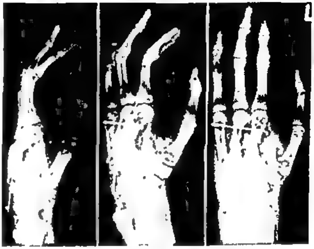
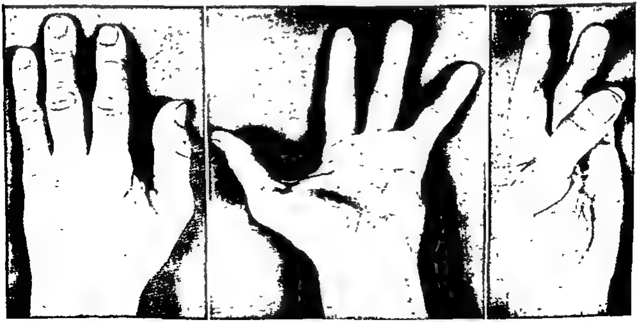


FIG. 2. J. E. (*Top, left*) Shotgun wound of hand several hours after injury. Wound of entrance on palm, wound of exit on dorsum. Preoperative dorsal view. (*Right, upper*) Preoperative roentgenograms showing extensive compound fractures, loss of portion of middle finger metacarpal head and proximal phalanx. (*Right, lower*) *Postoperative roentgenogram of hand showing transfer of index finger to base of middle finger metacarpal*, fixation of fractures by Kirschner wires, amputation of middle finger. (*Below*) Dorsal view 1 year after injury, postoperative volar view, postoperative opposition of thumb to little finger.



quently has a much greater function than a hand of a similar form or shape with an acquired deformity due to severe trauma.

I should like to point out some of the major problems that we have encountered in severely injured hands that involve multiple tissues.

The first such problem is the crush avulsion type of injury from severe blunt trauma involving crush avulsed skin plus disinsertion of proximal tendon ends and, occasionally, median and/or ulnar nerves as well (Fig. 1). Such severely injured deep tissues can be repaired by tendon transfers and nerve repair with a very guarded prognosis. The success of such repair depends upon the objective, rather than hopeful, evaluation of the circulation to the skin of the avulsed flap. If the circulation is judged to be inadequate in the initial analysis, it is better to sever it and replace the avulsed skin with a full-thickness graft rather than suture it back. Skin necrosis is so detrimental to the final result that proper primary skin cover should take precedence over the more dramatic disinsertion of the tendons and/or the nerves.

Another type of problem is the primary care of a gunshot wound seen early with optimum hospital conditions (Fig. 2). Such conditions include the well-known concepts of atraumatic care, meticulous débridement, immunizations, antibiotics, proper operating facilities, including anesthesia, proper postoperative dressing and physiotherapy. We feel that all these things justify much more extensive primary reconstruction of such gunshot wounds. In general, we feel that all tissues other than flexor tendons in the hands or the fingers should be actively considered for reconstruction. The three most important phases of surgical treatment in such a wound are (1) meticulous systematic débridement of all injured surfaces, which usually takes at least one half of the operating time; (2) careful alignment of fractures, usually requiring internal fixation; and (3) complete skin coverage, usually with supplementary split-thickness skin grafts and/or local rotational flaps All three phases out-

Figs. 3 and 4, W. F. Fig. 3. (*Top*) After thorough débridement and fixation of fractures by internal Kirschner wires prior to application of abdominal pedicle in severe cornpicker injury with multiple tissues involved. (*Center*) Preoperative roentgenogram showing multiple severe compound fractures with marked displacement. (*Bottom*) Postoperative roentgenogram showing bone graft of thumb and healing of metacarpal fractures.

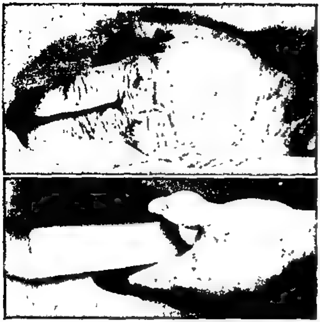


FIG. 4. (*Top*) Final dorsal view. (*Bottom*) Postoperative grasping function.

lined above are important. However, immediate success in wound healing depends more on the débridement and skin coverage, whereas the late functional result, assuming good healing, directly reflects the bony architecture obtained by proper reduction and fixation.

Another problem has been our disappointment in the final functional result in these multiple-tissue injuries, such as corn-picker injuries, which could not be closed except by the use of a distant pedicle of skin and subcutaneous tissue, usually from the abdomen (Figs. 3-5). In our experience, such surgically created wounds are rarely absolutely closed. Thus, an open wound for some weeks causes maceration, deep cicatrix and late functional impairment. Also, the hand

FIG 5, W H (*Top, left*) Cornpicker injury. Dorsum and volar surface of hand seen 1 month after injury with exposed phalanges and granulating wound on dorsum. (*Top, right*) Volar view 1 month after injury with granulating wound of palm. (*Bottom, left*) Lateral view with extension of fingers and thumb (*Bottom, right*) Volar view to show grasping mechanism.

dressing against the trunk is merely absorptive and does not compare in efficiency with the hand dressing of a nonattached upper extremity. A further obvious difficulty with elevation predisposes to even more edema. All these factors have made us very reluctant to resort to immediate abdominal pedicles of skin and subcutaneous tissue. Instead, if at all possible, the preference is to close the wound by local shifts of skin and subcutaneous tissue by proper local flaps or relaxing incisions, split- or full-thickness skin grafts, and/or filet flaps from amputated digits.

Another type of multiple-tissue injury seen frequently is the rotary power-mower injury. Usually this involves loss of skin as well as compound fractures and injuries to nerves and partial division of tendons. Here the skin replacement following adequate débridement is the most important factor in the primary care. Split- or full-thickness skin grafts, cross-finger pedicles and, possibly, palmar flaps in that order, used judiciously, have been the procedures most useful for early primary healing and optimum final result.

Another common injury involving multiple tissues is the buzz saw or planer injury or other similar injuries from use of home power tools. The accurate alignment of the transverse compound fractures usually resulting from this wound and the resulting joint stiffness if articular surfaces are involved have been more severe problems than skin replacement. Experience in anticipating final range of motion at the severely injured joints aids in the immediate prognosis. If the articular surfaces of the interphalangeal joints have been entered and comminuted by such severe mechanical trauma, one must anticipate a severe loss of motion. Also, the possibility that the 10° to 40° of motion that may result may well be painful. Secondary fibrous ankylosis of torn or immobilized collateral ligaments has been a severe problem in the final functional result. If one can leave these fingers with good sensation, circulation, nontender scars and reasonable alignment of the bony fragments, the final functional result is usually quite good, and little secondary reconstructive surgery can, or should, be done. Occasionally an arthrodesis of a partially stiff and painful interphalangeal joint is a very useful later procedure.

It has been mentioned that the acquired deformity of noninjured parts is as important for the final functional result as the specifically injured parts. This entails a brief discussion of practical aids in the postoperative care of the severely injured hand. A snug, but not tight, fluffy pressure dressing with a plaster splint extending to the proximal one third of the forearm, with the hand always in a position of function, has been the basic dressing for all severely injured hands. This dressing usually is left undisturbed for 1 week unless there are obvious signs of infection. Then immobilization for a second week will ensure that the hand has the minimal edema. Gentle passive and active mobilization of all noninjured parts at the end of the second week is extremely important. Without exception, our best results in preventing stiffness have come from simple, accurate instructions for passive and active mobilization of *all* joints that could be carried out by the patient almost constantly during the waking hours. Elastic splinting and physiotherapy are regarded merely as supplements, not replacements for active mobilization by the patient. Such splinting usually is applied during the sleeping hours. The hands with severed tendons and fractured bones are mobilized at the end of 3 weeks in the majority of cases, and always by the end of 4 weeks. One may get a good-looking roentgenogram of a stiff digit, but the final function always is poor.

To summarize, the complex functional anatomy of severely injured hands demands accurate analysis of five tissue areas: skin, nerve, bone, joint and tendon. This analysis includes a general prognosis for these tissues and a summation for total function of the hand. Numerous reconstructive surgical procedures can be utilized to salvage severely

injured hands by proper application. The only absolute indication for primary amputation in the hand is nonviability of the part. The immediate reconstructive surgery must be followed by active mobilization by the patient after proper healing. Only in this way can an acquired deformity of severe stiffness and malfunction be prevented. The final functional result will more than justify the detailed analysis, meticulous reconstructive surgery and demanding postoperative mobilization.

BIBLIOGRAPHY

Allen, H. S.: Management of lacerations of flexor tendons within the digits, S. Clin. North America 35:189, 1955.

Bunnell, S : The early treatment of hand injuries, J. Bone & Joint Surg. 33A:807, 1951.

———: Splints for the hand *in* Orthopedic Appliances Atlas, vol. 1, p 277, Ann Arbor, Mich , Edwards, 1952.

———: Surgery of the Hand, ed. 3, Philadelphia, Lippincott, 1956.

———: Surgery in World War II—Hand Surgery, p 20. Medical Department, U.S. Army. Office of the Surgeon General, Department of the Army, Washington, D.C., 1955.

Evans, E. M.: The treatment of major injuries of the hand, Brit. J. Plast. Surg 2:150, 1949

Farmer, A. W.: The treatment of avulsion injuries by replaced skin grafts, S. Clin. North America 23:1440, 1943.

Flatt, A. E.: Minor hand injuries, J. Bone & Joint Surg. 37B:117, 1955.

Flynn, J. E.: Open wounds of the hand, New England J. Med. 250:793, 1954.

Furlong, R.: Injuries of the Hand, Boston, Little, 1957.

Koch, S. L.: Fractures involving the hand and the position of function (editorial), Surg., Gynec. & Obst. 89:644, 1949.

———: Injuries of the parietes and extremities, Surg., Gynec. & Obst. 76:1, 189, 1943.

McCormack, R. M.: Final repair of the severely injured hand, Plast. & Reconstruct Surg 3:687, 1948.

McDonald, J. J., and Webster, J. P.: Early covering of extensive traumatic deformities of the hand and foot, Plast. & Reconstruct. Surg. 1:49, 1946.

Rank, B. K., and Wakefield, A. R.: Surgical Repair As Applied to Hand Injuries, Edinburgh, Livingstone, 1953.

Chirurgia Reconstructori e le Maneamento Immediate de Manos Severmente Lesionate

Summario in Interlingua

In le conception moderne, le chirurgia reconstructori include non solmente le secundari intervention chirurgic in partes que es severmenta deformate—de origine congenite o de origine acquirite—sed etiam le disposition del chirurgia primari de maniera a effectuar le maximo de beneficio functional. In le caso del mano, iste conception del chirurgia reconstructori es particularmente impoetante, proque le ultime function de iste complexe parte del organismo es directemente proportional al successo del immediate maneamento chirurgic. Tamen, le cursos universitari de practica chirurgic resulta rarmente, pro le apprehendente, in le mesme grado de expertia con respecto a omne aspectos del structuras interessate in severmente lesionate manos. Assi, currentemente, le ben trainate chirurgo trova que su plus difficile problemas concerne complexos histologic con que ille es le minus familiar. Iste factos relative al programmas universitari de exercitio chirurgic exerce un influentia super le comportamento del chirurgo in le analyse de casos de sever lesiones manual. Illos affice su ultime judicamento chirurgic.

Initialmente le problemas a resolver es usualmente concernite con le alternativa de reconstruction o amputation. Le sol indication absolute pro le amputation primari del mano es un perdita irreversibile del provision de sanguine a ille parte. Subsequentemente le detaliate analyse del manovras reconstructori concerne cinque areas histologic: Le

pelle, le nervos, le ossos, le articulationes, e le tendines. In general, si tres o plus de iste areas es irreversibilemente lesionate, il ese melior amputar initialmente in loco de essayar dubitose mesuras reconstructori.

Le ultime prognose functional etiam reflecte le mechanismo del lesion. Isto significa que le prognose de un lesion contusional es pessimista per contrasto con le prognose in casos de laceration. Le plus importante factor a considerar in le prognose final es le rigiditate residue del mano, e un accurate prediction del resultante grado de rigiditate es extrememente difficile a facer al initio del tractamento. Le factores que determina iste *prognose es le mechanismo del lesion,* le grado de destruction in le cinque mentionate areas histologic, le etate del patiente, le motivation in le uso subsequente del mano, e a vices un non-expectate complication post-operatori. Le utilitate del mano depende del controlo que le individuo pote exercer super illo e non de su forma o de su deformation.

Specific lesiones de alte grados de severitate que affice plure areas histologic es discutite. Istos es: (1) Le typo de lesion a contusion avulsional, con disinsertion de terminos proximal de tendine. (2) Mancamento primari de lesiones per armas de foco, promptemente presentate e tractate sub optimal conditiones hospitalari. (3) Disappunctamento in le ultime grado de restablimento functional in lesiones que affice plure areas histologic e que require, pro effectuar le clausion initial, le uso de distante pediculos de pelle. (4) Lesiones per instrumentos motorisate, afficiente multiple areas de histo, specialmente al superficies extensori del digitos. Le prevention de rigiditate residue ha essite effectuate le plus frequentemente per nihil plus que accurate instructiones pro le mobilisation passive e active de omne le articulationes que es attingibile per le patiente mesme. Le application de apparatos elastic e le uso de physiotherapia es supplementos e non reimplaciamentos del mobilisation active per le patiente. Solmente assi pote esser evitate le acquirite deformitate de sever grados de rigiditate e de insufficientia functional.

injured hands by proper application. The only absolute indication for primary amputation in the hand is nonviability of the part. The immediate reconstructive surgery must be followed by active mobilization by the patient after proper healing. Only in this way can an acquired deformity of severe stiffness and malfunction be prevented. The final functional result will more than justify the detailed analysis, meticulous reconstructive surgery and demanding postoperative mobilization.

BIBLIOGRAPHY

Allen, H. S.: Management of lacerations of flexor tendons within the digits, S. Clin. North America 35:189, 1955.

Bunnell, S.: The early treatment of hand injuries, *J. Bone & Joint Surg. 33A:807, 1951.*

———: Splints for the hand *in* Orthopedic Appliances Atlas, vol. 1, p. 277, Ann Arbor, Mich., Edwards, 1952.

———: Surgery of the Hand, ed 3, Philadelphia, Lippincott, 1956.

———: Surgery in World War II—Hand Surgery, p 20. Medical Department, U S. Army. Office of the Surgeon General, Department of the Army, Washington, D.C., 1955.

Evans, E. M.: The treatment of major injuries of the hand, Brit. J. Plast. Surg. 2:150, 1949.

Farmer, A. W.: The treatment of avulsion injuries by replaced skin grafts, S. Clin. North America 23:1440, 1943.

Flatt, A E.: Minor hand injuries, J. Bone & Joint Surg. 37B:117, 1955.

Flynn, J. E.: Open wounds of the hand, New England J. Med. 250:793, 1954.

Furlong, R.: Injuries of the Hand, Boston, Little, 1957.

Koch, S. L.: Fractures involving the hand and the position of function (editorial), Surg, Gynec. & Obst. 89:644, 1949.

———: Injuries of the parietes and extremities, Surg., Gynec. & Obst. 76:1, 189, 1943.

McCormack, R. M.: Final repair of the severely injured hand, Plast. & Reconstruct. Surg. 3:687, 1948.

McDonald, J. J., and Webster, J. P.: Early covering of extensive traumatic deformities of the hand and foot, Plast. & Reconstruct. Surg 1:49, 1946.

Rank, B. K., and Wakefield, A. R.: Surgical Repair As Applied to Hand Injuries, Edinburgh, Livingstone, 1953.

Chirurgia Reconstructori e le Maneamento Immediate de Manos Severmente Lesionate

Summario in Interlingua

In le conception moderne, le chirurgia reconstructori include non solmente le secundari intervention chirurgic in partes que es severmenta deformate—de origine congenite o de origine acquirite—sed etiam le disposition del chirurgia primari de maniera a effectuar le maximo de beneficio functional. In le caso del mano, iste conception del chirurgia reconstructori es particularmente impoetante, proque le ultime function de iste complexe parte del organismo es directemente proportional al successo del immediate maneamento chirurgic. Tamen, le cursos universitari de practica chirurgic resulta rarmente, pro le apprehendente, in le mesme grado de expertia con respecto a omne aspectos del structuras interessate in severmente lesionate manos. Assi, currentemente, le ben trainate chirurgo trova que su plus difficile problemas concerne complexos histologic con que ille es le minus familiar. Iste factos relative al programmas universitari de exercitio chirurgic exerce un influentia super le comportamento del chirurgo in le analyse de casos de sever lesiones manual. Illos affice su ultime judicamento chirurgic.

Initialmente le problemas a resolver es usualmente concernite con le alternativa de reconstruction o amputation. Le sol indication absolute pro le amputation primari del mano es un perdita irreversibile del provision de sanguine a ille parte. Subsequentemente le detaliate analyse del manovras reconstructori concerne cinque areas histologic: Le

pelle, le nervos, le ossos, le articulationes, e le tendines. In general, si tres o plus de iste areas es irreversibilemente lesionate, il ese melior amputar initialmente in loco de essayar dubitose mesuras reconstructori.

Le ultime prognose functional etiam reflecte le mechanismo del lesion. Isto significa que le prognose de un lesion contusional es pessimista per contrasto con le prognose in casos de laceration. Le plus importante factor a considerar in le prognose final es le rigiditate residue del mano, e un accurate prediction del resultante grado de rigiditate es extrememente difficile a facer al initio del tractamento. Le factores que determina iste prognose es le mechanismo del lesion, le grado de destruction in le cinque mentionate areas histologic, le etate del patiente, le motivation in le uso subsequente del mano, e a vices un non-expectate complication post-operatori. Le utilitate del mano depende del controlo que le individuo pote exercer super illo e non de su forma o de su deformation.

Specific lesiones de alte grados de severitate que affice plure areas histologic es discutite. Istos es: (1) Le typo de lesion a contusion avulsional, con disinsertion de terminos proximal de tendine. (2) Maneamento primari de lesiones per armas de foco, promptemente presentate e tractate sub optimal conditiones hospitalari. (3) Disappunctamento in le ultime grado de restablimento functional in lesiones que affice plure areas histologic e que require, pro effectuar le clausion initial, le uso de distante pediculos de pelle. (4) Lesiones per instrumentos motorisate, afficiente multiple areas de histo, specialmente al superficies extensori del digitos. Le prevention de rigiditate residue ha essite effectuate le plus frequentemente per nihil plus que accurate instructiones pro le mobilisation passive e active de omne le articulationes que es attingibile per le patiente mesme. Le application de apparatos elastic e le uso de physiotherapia es supplementos e non reimplaciamentos del mobilisation active per le patiente. Solmente assi pote esser evitate le acquirite deformitate de sever grados de rigiditate e de insufficientia functional.

8

The Crushed Hand*

MICHAEL L. MASON, M.D., F.A.C.S., AND JOHN L. BELL, M.D., F.A.C.S.

This particular entity in the various injuries which the hand may sustain presents, in addition to the general problem of the care of open wounds, the management of all the tissues of the hand: bones, joints, muscles, tendons, nerves and skin. Often there is traumatic amputation of one or more digits, loss of a greater or a lesser amount of skin; and the fingers are so badly crushed that their vitality is highly questionable. If they are viable, often there is no evident possibility of restoring them to function. Frequently the temptation exists to carry out extensive amputation, often of the entire hand, in the face of what appears to be a hopeless situation. It is when one is confronted with such a hand that a basic philosophy underlying the management of such cases is most welcome. The problem is to salvage a functional unit from a seemingly hopeless tangle of tissues. Usually, any moving and sensitive parts left may be restored to some function which, minimal though it may be, is much more valuable than the most beautiful prosthesis.

BASIC PRINCIPLES OF CARE

Actually, the problem is the same in the case of hand injuries, whether they are large or small, whether tissue damage is extensive or minimal. There are a few basic principles underlying care that need only amplification to make them applicable. These are, first, to render the wound surgically clean; second, to rid the wound of devitalized tissue; third, to restore anatomic relationships so far as the condition will permit; fourth, to close the wound with skin; fifth, to splint the part in the position of function to promote healing and favor functional return. The first goal that the surgeon must achieve is that of primary healing of the wound; the second goal is to restore function. It cannot be assumed by any means that functional restoration must be secured at first instance. This is the first temptation that the surgeon must resist in caring for the injury in question Extensive reparative surgery in a hand already badly handicapped by the original trauma may wreck the patient's only chance of a functioning hand. The surgeon must remember that unless primary healing can be secured, later reparative surgery may be difficult, if not impossible, is unduly delayed and certainly less promising. Nothing should be done in the way of repairs unless it is certain that the tissues are healthy enough to tolerate such surgery.

What, then, are the steps to be taken in the care of an injured hand that has received widespread highly traumatizing damage? The two factors of immediate concern are wound contamination and tissue devitalization. It is on an appreciation of these factors that present-day wound care is based.

BACTERIAL CONTAMINATION

Contamination of the open wound occurs at the time of the initial injury with entrance

* From the Division of Surgery, Northwestern University Medical School, and Passavant Memorial Hospital, Chicago.

of organisms from the injuring agent and from the skin and the clothing of the patient. These organisms may or may not be highly virulent. More often than not their invasive powers are not great, and a certain period of time is required for them to become virulent. Friedrich's experiments of 60 years ago pointed out the way to deal with this problem, and principles of care based on these experiments have stood the test of time. To a large extent these contaminants may be removed from the wound by early cleansing and excision within 6 to 8 hours following injury. Those still remaining are reduced in number and usually are taken care of readily by healthy surrounding tissue. However, a second and much more important source of bacterial contamination obtains after wounding; it is human and environmental. Organisms from these sources gain entrance to wounds subsequent to injury; they come from the nose and the throat of the patient himself, of doctors, nurses and attendants; from inquiring fingers and fingered dressings; from the air and the blankets of hospital wards; from dressing rooms and operating rooms. Frequently these bacteria are immediately invasive or establish themselves very quickly. They may be introduced into wounds not once but repeatedly with each exposure of the open wound for inspection and dressings. The rapid dissemination of bacteria from infected wounds throughout hospital wards has been amply proved by Colebrook and his associates in their burn wards. It was a problem noted long ago by Pirogoff when he stated that he would rather care for his wounded soldiers in a peasant's miserable hovel than in a hospital. Today, also, we are confronted with a problem that the Germans have rather fittingly called hospitalism. The offending organism is an antibiotic-resistant staphylococcus. Probably this organism has arisen by a process of natural selection in its struggle for existence with modern antibiotics and is a manifestation of nature's way of dealing with these problems. The current reaction to the development and the spread of this organism is to decry the widespread use of antibiotics, since their use has called forth the development of this variety of bacteria. While this is true enough, one could have anticipated such a course of events, and, resistant or nonresistant, these bacteria still have to gain entrance to wounds to cause trouble.

The universal use of antibiotics is undoubtedly the reason for the increase in infections seen in so many institutions; not, however, because of growing bacterial resistance but because the surgeon is placing too much reliance on the antibiotics to control the development of infection and possibly has become somewhat less careful in his application of control measures to prevent bacterial contamination. This antibiotic-resistant staphylococcus is an excellent test organism for the efficacy of aseptic measures. A somewhat similar problem was solved many years ago by Frank Meleney, but, like many important contributions, its full significance was appreciated by only a few, and the advent of antibiotics seemed to permit the surgeon to pay less attention to strict asepsis.

This preamble is to emphasize the need for the strictest aseptic care in handling the open wound. Prevention of secondary contamination should start with first aid and continue until the wound is closed. The crushing wound, despite the fact that it appears to be about as contaminated as it can get, demands the same protection as the clean operative incision. It should be covered over as first aid and not uncovered until the patient reaches a properly organized emergency room, where it is inspected with the same observance of aseptic care that would be accorded the open abdomen in the operating room. Everyone, including patient, doctor and all personnel, should wear caps and masks, and dressings should be carried out with strict aseptic technic.

It would hardly seem necessary to stress the need for strict asepsis at the time of surgery; however, certain factors that often

are forgotten contribute to contamination in the operating room. These have to do with the screening of personnel who are potential carriers of invasive bacteria, with control of contaminants, of blankets and restriction of operating-room traffic. The search for sources of bacterial contaminants is most laudable. However, in our zest we often neglect the most obvious and important.

The need for protection dictates also one important step in the initial surgery, namely, primary closure of the wound if at all feasible. So long as the wound remains open, it is subject to contamination, and only in the rarest instance should civilian injuries be left open for secondary closure.

The need for protection following surgery obtains until healing has been secured. All dressings should be carried out with surgeon or assistant and all bystanders and patient being masked. The handling of dressings after surgery should be done with sterile instruments to avoid finger contamination.

This discussion on the philosophy of aseptic care would seem to be superfluous and hardly to the point in discussing crushing injuries; however, the advent of hospitalism points up the present-day problem of contamination. This problem is very important in the crushing injury, since not only are large areas often opened up to bacterial invasion but the crushed tissues have little power to combat invaders even in small numbers.

The second important consideration in the immediate management of the crushing injury is the presence of dead and devitalized tissue that requires removal. This tissue must be excised as the initial operative procedure so that when the surgeon comes to repair the wound, the tissues with which he has to deal are viable. Viable tissue also is a significant factor in the control of infection, since healthy tissue can deal with a moderate amount of contamination, whereas dead tissue and blood clots form excellent media for bacterial growth.

PHASES OF SURGICAL CARE OF CRUSHING INJURIES

Based on the foregoing considerations, the care of the crushing injury may be outlined as follows:

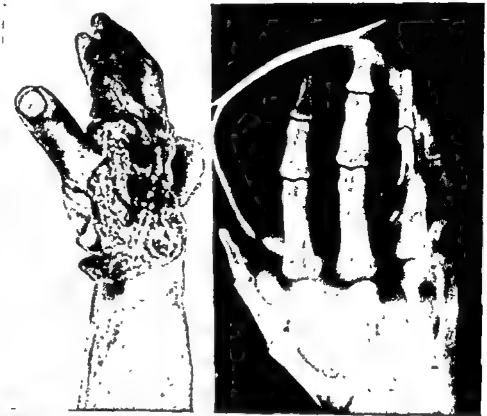
First Aid

As first aid the hand should be covered with a voluminous dry sterile dressing bandaged on snugly, and, if available, a splint should be applied. This dressing is left in place until the patient reaches the place where definitive care is to be given. Here a careful evaluation is made of the patient and his injury. It is important to determine the time that has elapsed since injury, since, if it is a matter of over 6 to 8 hours, the chances that contaminants have become established are very great. The nature of the wounding agent or the manner in which the wound was received is often of importance in making a decision concerning tissue damage. For example, a crush in a light wringer would be very different from that sustained in a punch press. Crushing injuries sustained between hot rollers produce a quite different type of injury from that in which the rollers are cold.

Cleansing

The initial treatment consists of careful washing of the part with soap and water. Usually this has to be carried out under general anesthesia with a blood-pressure cuff applied to furnish a bloodless field, since these injuries are quite likely to bleed during washing. First the wound itself is covered with a sterile dressing, and the remainder of the hand and the forearm to the elbow is washed for 10 minutes with soft cotton fluff squares. Then the surgeon changes his scrub set, dons a fresh pair of sterile gloves and washes the wound itself with soap and water for an equal period of time. Next the part is rinsed well with warm sterile saline solution and is draped for surgery. No antiseptics are used either on the skin or in the wound; the tissues have suffered sufficient damage

FIG. 1. S. R., age 28. Crush of the hand with extensive dorsal destruction of bone and tendon and irreparable injury to ring and little fingers. After filleting the bone from the ring and the little fingers, sufficient pedicled skin was salvaged to close the dorsal wound. Alignment of the bony framework was maintained by molding the hand into the position of function. Primary healing of the wound permitted the insertion of a cortical bone graft to restore length of the second metacarpal 4 months after injury. Extensor-tendon grafting was performed 7 months after injury. (*Top, left*) Appearance of the open wound prior to initial surgery. (*Top, right*) Roentgenogram of hand prior to initial surgery. (*Bottom, left*) Roentgenogram of hand postoperatively showing maintenance of length in spite of loss of metacarpal substance. (*Bottom, center*) Roentgenogram showing cortical bone graft of second metacarpal. (*Bottom, right*) Appearance of hand 7 months after injury and prior to extensor-tendon grafting.



without the addition of not only useless but harmful chemicals.

Wound Excision

The very important phase of wound excision now is undertaken. This procedure is designed to remove all tissue so severely damaged that it will not survive. It is not designed primarily to remove contaminants, although it does remove some. Healthy tissues can cope with minimal bacterial contamination and can heal.

The excision starts with the skin and proceeds through all damaged tissues layer by layer. Each tissue will present its own problem, but probably the most troublesome will be that of the skin. There are two factors here: the first is the crushing of the skin that damages it directly, often so severely that it cannot survive; the second factor concerns the vascular supply. Very frequently the skin is torn back in flaps which either do not carry in sufficient blood supply to ensure survival or venous return is obstructed Often the vessels to these flaps are obliterated by thrombosis, a complication that is likely to occur if the flap has been bent back on itself by the application of first-aid dressings.

Decision as to skin excision must be made carefully, since we do not wish to sacrifice needlessly, nor do we wish to leave attached flaps that will become necrotic, especially if they have been laid back over tendons and joints. Needless sacrifice will make the eventual closure more difficult than it should be. Preservation of devitalized flaps may lead to serious wound disturbances, and closure will be necessary by graft later on, after removal of dead skin, often in a less favorable wound. When doubt exists as to viability of skin, often it is helpful to use what we have called the tourniquet test. The wound is covered with moist compresses and the blood-pressure cuff is released. After about 5 minutes of compression on the wound, the compresses are removed, and the return of circulation in the skin flaps is observed. If the flaps become pink and bleed, they should survive. If, however, the flap remains white or becomes black from venous obstruction, it will not survive. Excision then is carried back to the point at which bleeding occurs or the duskiness ends.

No attempt is made at this time to smooth off jagged skin edges; all viable tags are left in place so that when time for closure comes they are available. Often they may be dovetailed into each other to make satisfactory cover. Likewise, the skin of irreparable digits is preserved by deboning the finger, leaving the skin, which often may be turned over as a local flap when the time for closure comes (Fig. 1).

Muscle is excised as indicated, as is gravely soiled subcutaneous tissue. Ordinarily tendon is not widely excised unless it is badly shredded or exposed. Nerve, too, is excised only minimally, unless the nerve is one for a digit already amputated traumatically. Bone chips are left in place if they have any soft-tissue attachment, since often they may be molded into position in the fracture area.

During the time of excision the extent of damage is ascertained accurately, and nerves and tendons are identified. When excision is complete, the surgeon knows the full extent of the injury and that the tissues left are viable. He must then decide what he can do with these tissues to favor return of function.

Repair

Confronted with extensive skin loss, with nerve and tendon damage, with fractures and joint damage, with tissues that have been badly insulted and with healing powers impaired, it is obvious that extensive reparative surgery is not indicated (Fig. 2).

If the facilities are available, usually it is permissible to carry out nerve repair of both the larger trunks and the digital branches. If, for some reason, repair cannot be carried out, it is helpful to tack the nerve ends together with very fine (6-0) sutures intro-

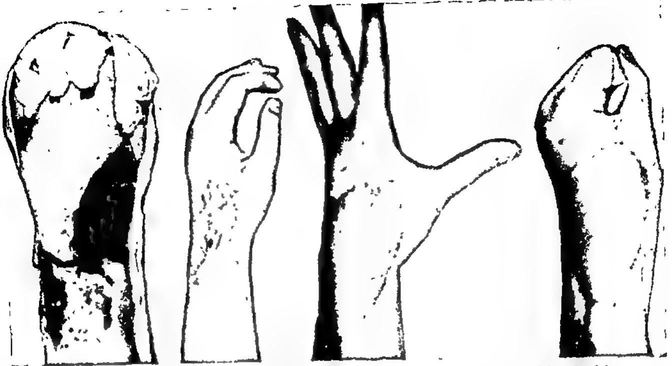


FIG. 2. J. S., age 18. Explosive injury of hand and wrist. Wound excision had been performed elsewhere 4 days previously. No evidence of infection was present, and minimal further excision permitted closure with a split-thickness skin graft. After healing, an abdominal pedicle flap was applied. Tendon grafts were inserted later beneath the flap to the thumb, the index and the middle fingers.

From left to right: (1) Appearance of the wound 4 days after initial wound excision. (2) The closed wound prior to excision of scar and the application of abdominal pedicle flap. (3) Two-year follow-up photograph showing extension of digits following extensor-tendon grafts to thumb, index and middle fingers. (4) Two-year follow-up showing active flexion of the digits.

duced as close as possible to the ends and only through the perineurium, to avoid scarring in the substance of the nerve. If the surgeon is trained in nerve repair, end-to-end suture frequently is justified. If he is not so trained, and if fine sutures are not available, then it is better to leave the nerves alone.

As to the tendons, which often are divided and crushed, occasions are few indeed on which tendon repair of any sort is justified. This certainly applies 100 per cent in the case of the flexor tendons, while in a few instances extensor-tendon repair is permissible.

The reasons for omitting tendon repair are several. Most important is the fact that the crushed tissues heal slowly and often with considerable edema, due to the nature of the injury itself. The tendons themselves are likely to be crushed and damaged, are difficult to handle and, if they heal, do so with a large callus and extensive adhesions. The search for and mobilization of tendon ends add further damage to the tissues and make for reaction and scar. Fractures, if present, are certain to become adherent to overlying tendons, especially if suture has been carried out. Also, if accessory incisions are needed to mobilize tendon ends, they may jeopardize the flap circulation. Finally, skin loss may be such that the site of tendon repair cannot be covered with an adequate flap of skin.

Occasionally it is possible to apply a few fine silk sutures into extensor tendons in instances in which adequate skin coverage can be secured.

Joint spaces must be closed. This may be possible by suture of the joint capsule or, if this is not possible, by bringing neighboring tissues together.

Figs. 3 and 4. M. M. Open fractures of hand usually may be molded into satisfactory position at time of initial surgery. Fig. 3 (*Above*) Preoperative roentgenogram showing fractures of the middle phalanges of the middle and the ring fingers. (Mason, M. L.: Indust. Med. 20:260-263)

Open Fractures

It is essential at this time to restore the framework of the hand. The importance of this cannot be stressed too strongly. If the initial opportunity passes, later correction of fractures becomes increasingly difficult, and rehabilitation is postponed longer. In general, the simplest method possible should be used to gain fracture reduction. Whatever method is used, the guiding principle is to place the hand in the position of function.

In violent crushing injuries of the hand, open fractures occur commonly and may be multiple. The problem of securing adequate soft-tissue and skin coverage over the bony injury continues to be more of a problem than the management of the fractures. Even though severely comminuted and displaced *fractures are reduced and maintained in* satisfactory position, failure of the overlying soft tissue to survive results frequently in infection and nonunion of the fracture. Subsequent amputation of a digit may be necessary because of this complication.

Reduction of open fractures is accomplished more readily than in similar closed fractures due to the advantage of direct visualization of the bone through the open wound. In open fractures, maintenance of reduction is obtained most often by immobilization of the injured part in a functional position on a suitable splint. Plaster casts are avoided because it is difficult to inspect and dress the all-important soft-tissue wounds without taking the chance of disturbing the position of the fractures. We have seldom used skeletal traction in the management of hand fractures. The banjo type of splint never is used because of the irreparable loss of function that occurs after immobilization of the digits in extension. In recent years, certain types of internal fixation have been advocated to maintain reduction of open fractures of the hand in clean cases. In crushing wounds associated with open fractures, each injury is so variable that no rigid set of rules can be relied upon, and in the majority of instances the most simple method of maintaining reduction of the fractures is the best.

The simplest forms of internal fixation of fractures should be reserved for injuries in which primary healing of the open wound can be confidently anticipated. In wounds which are seen late or in which infection is already established, closure may have to be postponed for a few days, but usually most civilian injuries can be closed primarily. Pieces of bone completely devoid of soft-

FIG. 4. (*Left*) Postoperative roentgenogram showing satisfactory reduction of fractures. The hand is placed on a universal splint. (*Right*) Follow-up roentgenogram showing healed fractures. (Mason, M. L: Indust. Med. 20:260-263)

tissue attachments should be removed in all cases of open fractures of the hand.

In a great many instances the hand may be molded simply over a universal splint into the position of function and the fractures thus reduced (Figs. 3 & 4). A large compression dressing is placed on the hand and aids in immobilization. Although we have relied strongly upon the use of the universal splint to maintain the proper reduction of multiple open fractures, fine stainless-steel wire sutures and small-caliber Kirschner wires have been useful adjuncts in selected cases (Fig. 5). Severely comminuted or unstable fractures near joints have been held together by drilling holes in the bony fragments and holding the pieces with No. 35 stainless-steel wire. Careful reconstruction of damaged joint capsules also facilitates the reduction of fractures near joints. Buried Kirschner wires, from .035 to .045 inches in diameter, have been employed for intramedullary fixation of fractures of the shaft or the neck of the metacarpal bones. Plating of the bones of the hand has not been used in our practice.

Open fractures of the distal phalanx are encountered frequently and usually present no problem, provided that the accompanying soft-tissue injury heals by primary intention. Failure of survival of the overlying soft tissues often is followed by a stubborn osteomyelitis of the distal phalanx, which may result in stiffening of the entire digit before the infection is conquered. Markedly displaced fractures of the distal phalanx are reduced by molding, and careful soft-tissue approximation without tension maintains the reduction. Free skin grafts to fill skin defects of the otherwise viable pulp are used to achieve closure without tension.

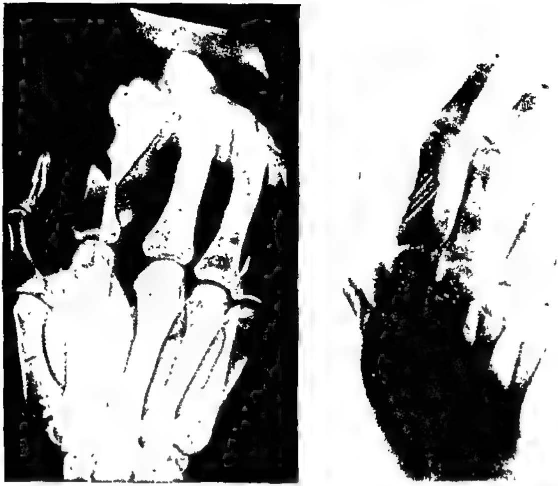


Fig. 5. M. S Internal fixation of open fractures should be used only when primary wound healing is anticipated. (*Left*) Open fracture of proximal phalanx of index finger. (*Right*) Reduction of fracture maintained by Kirschner wires.

Open fractures of the proximal and the middle phalanges often are angulated and displaced rotatorily. In these injuries direct visualization of the fracture site through the existing wound aids in accurate reduction, which can be maintained usually by flexion of the digit on a curved volar splint. When the finger is flexed, it should converge toward the tubercle of the navicular, otherwise a rotatory deformity will result in disability even though healing is sound. The finger never should be splinted in extension to maintain reduction of fractures of the middle and the proximal phalanges. This position seldom maintains reduction, and, of course, it leads to serious stiffening, which often is irreparable. It is rarely advisable to consider even the simpler forms of internal fixation in these open fractures because of the frequent precarious state of the overlying skin and subcutaneous tissue. On rare occasions pulp traction with the finger on a curved volar splint has been of value in controlling the phalangeal fracture.

Open fractures of the metacarpals vary in severity, and, fortunately, in spite of severe soft-tissue damage, many of them are displaced minimally and can be reduced by molding during wound repair. The position is maintained with the hand in the position of function on a universal splint. We have cut the ball of the universal splint in half to allow freedom of motion of uninvolved digits in some of the less severe cases. An aluminum splint to immobilize a single finger or the thumb in the position of function has been devised by Dr. Preston Burnham, of Salt Lake City. This splint permits motion

FIG. 6. W. H., age 35. Cold-roller injury to dorsum of left hand with open carpal dislocation and avulsion of all extensor tendons. At initial operation the joint capsule was repaired, and the extensor tendons were covered by shifting areolar tissue over them. Skin defect closed with split-thickness skin graft. Staged reconstruction was anticipated and started with the application of an abdominal pedicle flap 4 months later. Fusion of the wrist was performed after healing of the flap. The last stage of reconstruction was the insertion of extensor-tendon grafts 14 months after the injury.

From left to right: (1) Appearance of the crushing wound over the dorsal aspect of hand and wrist. (2) Appearance of the closed wound prior to the application of an abdominal pedicle flap 4 months after injury. (3) Appearance of hand prior to wrist fusion 7 months after injury. (4) Shows active extension after tendon grafting (22 months after injury). (5) Shows active flexion 22 months after injury.

(Stromberg, Mason & Bell: S. Clin. North America 38:1509)

of unimpaired digits while maintaining accurate reduction of the phalangeal fractures. Transverse fractures of the metacarpal shaft and neck frequently are unstable due to the extensive adjacent soft-tissue injury. If healing of the soft tissues without infection or necrosis is a certainty, transfixation or intramedullary fixation of the fracture with fine Kirschner wire is of value. We prefer not to allow the wires to protrude from the skin because of the danger of introducing infection into an area that is damaged severely. Fine stainless-steel sutures may be used to hold severely fragmented fractures in place in cases where primary healing can be anticipated.

In his zeal to secure accurate anatomic reduction, the surgeon must not neglect the soft tissues. Disturbed healing of skin and subcutaneous tissues about a fracture site can be disastrous. Even with loss of considerable substance of the metacarpals, a good functional result is obtained eventually if the alignment of the hand is satisfactory and the wounds heal primarily. In such cases bone-grafting may be performed secondarily at an early phase of total reconstruction of the hand. Staged reconstruction has to be anticipated in many of the severely damaged hands.

The sequelae following many intra-articular fractures are loss of motion and pain. Accurate reduction should be attained if at all possible. Fine wiring of the fragments and careful reconstruction of the surrounding joint tissues aid in accurate reduction of the open intra-articular fracture. Gliding tissue overlying the repair is necessary also in order eventually to achieve the maximum motion about the reconstructed joint.

FIG. 7. J. W., age 25. Sustained a crushing amputation of the tip of the right thumb with loss of the distal third of the distal phalanx. The nail bed was intact. A primary cross-finger flap was applied to the defect to preserve length of the thumb. (*Left*) Appearance of the open wound of the thumb. (*Center*) Shows the pedicle flap from the dorsum of the index finger attached to the thumb. The donor site on the index is covered by a thick split graft. (*Right*) Appearance of the thumb 6 weeks after injury. An adequate padding covers the bone, and the loss of length is barely noticeable.

CLOSURE

The final step in the operative procedure is to secure primary closure of the wound. This should be accomplished in all cases unless actual infection is present. Secondary closure, so much in use during World War II and the Korean conflict, is indicated only very rarely in civilian practice. Closure is the surest means of securing the wound against further contamination and of promoting rapid healing.

Closure may be quite easy or it may be quite difficult. When the time for closure comes, the surgeon will be very glad to have saved all viable skin, even irregular tags, since they are suitable often for closure. No skin will replace hand skin, and even irregular jagged edges, if sutured together carefully, will serve usually as definitive covering. When closure is not possible by suture, some type of skin graft is necessary. Usually the split graft works well, taken from the forearm for small areas or the thigh for larger areas. The graft is taken as thick as the surgeon judges to be compatible with a take. Obviously the thinner grafts take better, but they make less adequate definitive cover. Sometimes it is evident at the initial operation that the split graft will require later replacement by a thicker graft or a flap. This latter is especially true if it is necessary to carry out tendon repairs at a later date, after primary healing has been secured (Fig. 6).

At times the raw surface that requires coverage exposes bone, joint, nerve or tendon. Here free grafts are not suitable, and some type of flap usually is required. This may be local rotation or sliding flap, which is shifted over the defect, the bed of the flap then being covered by a split graft. A useful pedicle flap to cover volar digital wounds can be fashioned from the dorsum of an adjacent finger (Fig. 7). The cross finger flap is not bulky. Circulation of the flap usually is excellent. Sometimes a local flap cannot be raised, and the hand will have to be placed under a flap on the chest or the abdomen. We do not often use such a pedicled flap primarily, largely because frequently the flap must be made quite thick in order to ensure adequate circulation. At times this procedure will save a hand or a part that otherwise would be lost (Fig. 8).

In the overwhelming majority of cases we complete the primary operation with the

hand on a splint in the position of function under a compression dressing, with fractures reduced, nerves sutured or tacked together, and all wounds closed by suture or skin graft. This gives us the best assurance of securing primary healing. Further reconstructive surgery, if necessary, then can be carried out at an early date and has the best possible chance of success.

We have said nothing about the administration of tetanus antitoxin or toxoid. It should be understood that this protection should be given the patient. However, we should like to add a word concerning the use of antibiotics. The preliminary discussion concerning these agents should make our position clear. The antibiotics will help to protect the patient against bacteria sensitive to these agents. They are of no value if the organisms are not sensitive; hence we cannot depend upon them to control all contaminants. If we are careless in our asepsis and if we leave large amounts of necrotic tissue in a wound, we cannot expect antibacterial agents to help us. On the other hand, if we take meticulous care of wounds, practice aseptic surgery, carry out conscientious excision and primary closure, we have given the wound the best

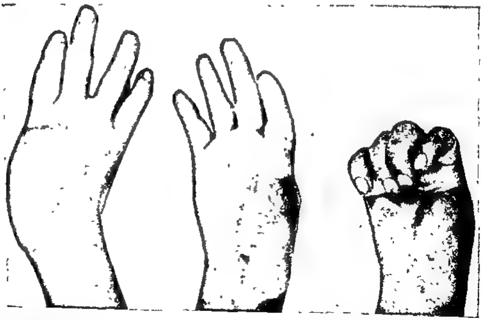


FIG 8. J. M., age 51 Crushing injury of right hand with traumatic amputation of the thumb. The index finger appeared to be damaged irreparably but was saved for possible future pollicization. After wound excision, a primary pedicle flap was applied to the radial aspect of the hand and the wrist to cover exposed bone, joints and tendons. Ulnar deviation of the hand later was corrected by attaching the extensor pollicis brevis and the abductor pollicis longus tendons to the base of the second metacarpal. Following this, the patient felt that the use of his hand was satisfactory and did not desire pollicization of the index finger.

(*Above*) The injury, showing the extent of the damage on the dorsal surface. (*Below, from left to right*) The condition of the hand 5 months after injury showing the ulnar deviation; showing active extension 11 months after the injury; showing active flexion.

(Stromberg, Mason & Bell: S. Clin. North America 38:1504)

chance of healing by primary intention. Then, as an added measure, we may administer an antibiotic, for its general effect, never locally. But only when all other measures are taken first can we feel that we have done our best. Primary healing of wounds occurred in the preantibiotic days, and our better results today, we feel, are due in large part to improved surgical technic, more respect for tissues and a realization of the significance of healthy tissue in the healing process.

BIBLIOGRAPHY

Allen, H. S., and Mason, M. L: A universal splint for immobilization of the hand in the position of function, Quart. Bull. Northwestern Univ. M. School 21:238-248, 1947.

Furlong, Ronald: Injuries of the Hand, pp. 186-188, Boston, Little, 1957.

Kilbourne, B. C., and Paul, E. G.: Do's and dont's in the treatment of hand injuries, S. Clin. North America 38:139-154, 1958.

Mason, M. L., and Bell, J. L.: The treatment of open injuries to the hand, S. Clin. North America 36:1337-1361, 1956.

Meleney, F. L.: The past 50 years in the management of surgical infections, Surg, Gynec. & Obst. 100:1-40, 1955.

Rank, B. K., and Wakefield, A. R.: Surgery of Repair As Applied to Hand Injuries, pp. 115-131, Edinburgh, Livingstone, 1953.

Tempest, M. N.: The emergency treatment of digital injuries, Brit. J. Plast. Surg. 7:153-161, 1954.

Le Mano Contundite

Summario in Interlingua

Le tractamento de vulnerationes contusional del mano representa un problema provocatori a causa del complexitate del damnification histic. Le objectivo es salvar le maximo possibile de function ab un apparentemente desperate tohu-bohu de histos. In multe casos, attention debe esser prestate al possibilitate de futur operationes de reconstruction. Le tentation de extense amputationes debe esser rejicite quandocunque possibile, proque omne function restaurate —mesmo minimal—es eminentemente plus utile que le plus belle prosthese. Le principios fundamental del tractamento initial es disveloppate. Primo, le vulnere debe esser facite chirurgicamente nitide. Secundo, histos disvitalisate debe esser eliminate. Tertio, le relationes anatomic debe esser restaurate in tanto que possibile. Quarto, le vulnere debe esser coperite con pelle. Quinto, ferrulas debe esser usate pro mantener le position functional del parte in question. Chirurgia reparatori que debe esser postponite deveni plus facile si le vulnere original es curate.

Es sublineate de novo le importantia del prevention de contamination bacterial ab fontes ambiental, specialmente a causa del recente augmento de racias staphylococcic *que es resistente contra le* antibioticos. Il es impossibile exaggerar le importantia del plus stricte attention a prestar al asepticitate del manovras technic durante e post le operation initial. Un certe laxitatet in le application del technicas aseptic in nostre hospitales, generate per un fide troppo absolute in le capacitate de antibioticos de prevenir infection chirurgic, es un del plus importante factores in le crescentia de un periculo que deveni de plus im plus prevalente in le mundo medical de nostre tempore.

Elementos cardinal in le prime manipulation chirurgic del mano contundite es mundification e excision del vulnere. Le manovra del excision ha le objectivo de eliminar omne histos que es ledite si severmente que illos non pote superviver. Durante le excision, omne le typos histic incontrate es evalutate

meticulosemente, e omne pecia de apparentia viabile es preservate. Un sacrificio innecessari de histo impedi le subsequente reparation e clauditura. Le test a tourniquet se ha provate de valor practic pro determinar le viabilitate de pecias de pelle.

Le reparo de dividite tendines flexori, associate con vulneres contusional, es usualmente contra-indicate. Del altere latere, le reparo de tendines extensori pote esser effectuate in certe casos. Frequentemente le reparo quasi o completemente definitive de nervos dividite pote esser effectuate. Le disponibilitate de adequate massas de histo molle e de pelle copertural es un condition indispensabile pro les restablimento del functiones de tendines, nervos, e articulationes post lor reparo.

Le restauration primari del structura skeletic del mano es importante, proque omne retardo in le correction de deformitates fractural resulta in difficultates in le processo del rehabilitation del mano e certo in un prolongation de ille processo. Usualmente le methodo le plus simple possibile debe esser usate pro mantener le reduction de fracturas aperte. Un principio fundamental in isto es que le mano—sin reguardo a qual methodo es usate—debe esser placiate in le position de su function. In le majoritate del casos, remodular le parte a in su position functional suffice pro tener le fracturas in un position satisfactori. Tamen, fixation interne per medio de suturas a fin filos metallic o filos de Kirschner es avantageose in casos seligite in que le resanation del vulnere primari pote esser expectate sin ulle question.

Le mesura final in le chirurgia initial es clauder le vulnere. In le practica del vita non-militar, excepte quando un infection es jam presente, le effectuation de un clauditura secundari es rarmente necessari. Clauditura per sutura sol es frequentemente impossibile. Graffos libere de pelle de spissitate findite debe esser usate in multe casos. Primari pecias pediculate ab sitos distante es applicate infrequentemente, sed illos pote esser necessari in casos in que pecias local non es disponibile e in que graffos libere non haberea un satisfacente vasculatura de base.

9

Reconstructive Surgery of the Hand Following Thermal Injuries

J. LEONARD GOLDNER, M.D.*

Thermal hand injuries may be localized to the hand only or occur as part of a generalized burn. In either case the initial treatment of the hand and the late reconstructive surgery follow the same pattern.

The severity and the extent of the original hand burn determine, in part, the magnitude of residual deformity (Fig. 1). Other factors, if not considered carefully, may complicate the problem and cause unnecessary deformity. These include delayed skin coverage, malposition of digits, closing the web spaces, and rigid and excessive immobilization of the fingers. Furthermore, lack of recognition of deformities that will respond readily to correction will add to the primary tissue damage and result in otherwise avoidable contractures (Figs. 2 & 3). Early skin-grafting, maintenance of interdigital web spaces, avoidance of vascular constriction, proper positioning of finger and knuckle joints, and establishment of early hand motion will, in part, aid in obtaining maximum recovery of hand function. Furthermore, each of these factors must be considered in conjunction with initial dressings, subsequent excision of necrotic tissue, application of useful splints and recognition of deformities as they occur.

In spite of adequate early treatment and prevention of certain deformities, extensive and selective tissue damage may result in joint, tendon and skin damage that must be *corrected* by appropriate surgery (Fig. 4, *top, left & right*). Splinting and stretching will not correct firm keloid or severely contracted ligaments. The operative procedure selected will vary according to the existing tissue changes. *The choice of surgical procedure will be determined after careful* analysis of each unit of the total deformity.

All basic units of the hand may be involved following thermal injury. Seldom, however, is one specific tissue alone involved in a *severe* burn. The tissues that may be involved alone or in combination are as follows:

1. *Skin and superficial* fascia.
2. Dorsal common extensor tendons, tendon sheaths and deep fascia.
3. Extensor hood, dorsal and volar capsule, and collateral ligaments of the metacarpophalangeal joints.
4. Extensor tendon and dorsal hood, dorsal and volar capsule, and collateral ligaments of the proximal and the distal interphalangeal joints.
5. Digital lateral bands of the intrinsic muscles.
6. Intrinsic muscles in the hand.
7. Palmar tissues comparable with dorsal structures (skin, fascia, tendons, capsule).
8. Articular surfaces of the hand and the finger joints.

The surgeon planning reconstructive *surgery* of a burned hand should be familiar with these structures and realize that the extent of surgery will vary from digit to digit. For this reason, a classification based

* Duke University Medical Center, Department of Surgery, Division of Orthopaedics.

FIG. 1. (*Top*) This boy held a live electrical wire in his hand, which was burned both superficially and deeply. It was impossible to determine the extent of tissue damage at the time of the original examination. Partial excision of necrotic tissue was done initially, and several days were allowed to elapse before additional excision of deep necrotic tissue was done. Split skin grafts were applied at the end of 10 days. The little finger was burned to the flexor tendon, with the joint and the nerves involved. It was impossible to salvage this digit. (*Bottom*) This is the hand several weeks after original injury. The little finger had no sensation. Grafting had allowed skin healing, but there was no joint motion, and firm contractures were present. Scarring in the palm was not severe. Amputation of the little finger and the distal two thirds of the fifth metacarpal was done. The good dorsal skin was utilized for partial replacement of the keloid in the palm.

on extent and severity of tissue injury is advisable.

GROUP 1—BURN INVOLVING SKIN AND SUPERFICIAL FASCIA

SKIN REPLACEMENT—GENERAL PRINCIPLES

Early placement of skin grafts aids in preventing contractures. Keloid formation may be excessive if there is prolonged delay in application of a split skin graft. If the burned hand is allowed to granulate and fibrose without the addition of skin, contractures of the digits usually occur in the direction of the burned surface (Figs. 2-5). Dorsal keloid may result in extension contracture at the metacarpophalangeal joints.

FIGS. 2 and 3 present same case. Fig. 2 (*Above*). (*Top, left*) Severe volar skin contracture involving palmar fascia and flexor tendon sheath in a child. Z-plasty is not advisable. Total excision of fibrotic skin and palmar fascia and wide excision of adjacent keloid give the best result with less chance of recurrence. In spite of this, bone growth may cause recurrent skin contracture necessitating repeated surgery until the child reaches adolescence. (*Top, right*) Shows the hand at the time of surgery, indicating the extent of the dissection and the necessary "side cuts." (*Bottom, left*) shows the motor branch of the median nerve under the hemostat. The local palmar fascia has been removed, and the neurovascular bundles have been cleaned of scar tissue. Skin was placed directly on the protected nerve, as well as on tendon sheaths, and healing occurred (*Bot om, right*) Shows the thick split graft taken from the thigh. The graft was placed a· oss the thumb web and tied in place with long silk sutures over a stent of soft dres· · . Adequate drainage was allowed through the graft.

and palmar keloid may result in flexion contracture at the interphalangeal joints. The digits may show limitation of flexion if fibrosis has occurred on the dorsum of the fingers, or limitation of extension if excessive scarring occurs on the palmar surface. The wrist may also be involved and may drift into flexion or extension with either medial or lateral deviation, depending on the site of the scar-tissue formation. If the position of function is not maintained from the time of injury by adequate firm splinting, the web space between the first and the second metacarpals will narrow rapidly, and contractures will occur about the wrist and the fingers.

Granulating surfaces not covered by split skin graft early may fill in gradually with dense keloid that limits flexion at the interphalangeal joints and the knuckle joints. The skin blanches with forced flexion, and full grasp is impossible. There may be limitation of flexion at the distal thumb joint because of fibrosis, as well as inability to abduct, rotate and oppose the thumb because of contracture of the thumb web. In addition, the little finger may be fixed in abduction, and the hand may be in ulnar deviation as a result of cicatrix extending from the fifth metacarpal to the distal end of the forearm. Correction of web space and joint contractures is possible by skin and fascia excision followed by replacement with thick split skin graft. The keloid is excised down to the subcutaneous fat and the tendon sheaths, leaving the dorsal veins intact. The peripheral margins of the excised areas are extended distal to joints and lateral or medial to the vertical axis in order to minimize recurrent scar contracture.

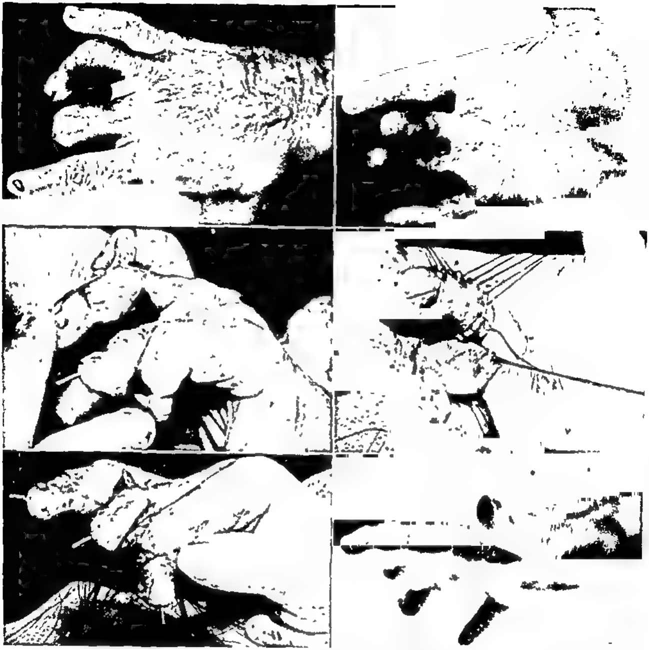
Fig. 3. The hand approximately 7 months after surgery with increased abduction and external rotation and good maturation of skin. No interference with motor power of thumb muscles. Additional surgery may be necessary in 2 or 3 years, as the child now is only 8 years old.

Surgical Technic

Usually the dissection is done using a tourniquet that may be released prior to final application of the skin in order to cauterize bleeding points. The electric or Padgett dermatomes are satisfactory for taking skin, and the thickness of the skin used varies according to the surface to be covered and the condition of the recipient site.

If multiple joints are involved, these may be held in full correction prior to application of the skin by the insertion of fine-gauge Kirschner wires across the joints, leaving ½ inch projecting for easy removal at the time of the first dressing (Fig. 4, *center, left & right, and bottom, left*). The metacarpophalangeal joints, for example, should be flexed to 110°, the proximal interphalangeal joints to 100°, and the distal joints to 145°. Figure 4, *bottom, right,* shows postoperative condition of the hand.

Figure 6, *left,* shows a hand with elongated and contracted dorsal interdigital web spaces prior to excision and replacement by diamond-shaped segments of split skin held in place by compression dressing utilizing peripheral sutures and tension sutures, and



FIGS 4 and 5 present same case. Fig. 4 (*Above*). (*Top, left*) This is the hand of a 9-year-old boy several months after a kerosene burn. The index finger was limited in flexion at the distal joint, and the nail bed was severely damaged. The long finger showed fixed flexion deformity at the proximal joint with limitation of flexion at the knuckle joint. The distal interphalangeal joint of the long finger also was in fixed flexion. The ring finger showed flexion deformity at the proximal joint with extension fixation of the distal joint. The little finger was limited in flexion and showed severe blanching of the dorsal skin when flexion was attempted. The limitation was particularly noticeable at the distal joint.

(*Top, right*) Shows the volar skin contractures, which were uncomfortable, cracked easily and became progressively worse because of bone growth.

(*Center, left*) Shows the hand at the time of surgery. Tenotomy of the common extensor tendon and the lateral bands was done on the dorsum of the middle phalanx of the *index finger* with complete release of the dorsal capsule at the distal joint but leaving adequate skin over the joint. Split skin graft was laid directly on the tendon and the bone, and tied in place with sutures over a dressing The remnant of fingernail was excised, along with complete excision of the damaged nail bed The *long finger* was treated by release of the volar contracture and brought into full extension, and the volar defect was filled with a thick split skin graft. The

(*Continued on facing page*)

inserted through the dorsum into the palm and tied over a stent. Burned fingernails and nail beds may result in painful and irregular nails and unhealthy matrix. The entire fingernail, nail plate and nail bed should be removed back to the level of the distal joint, and a small segment of bone removed in order to allow easy closure. In a female, for cosmetic reasons, an alternative method is excision of the fingernail and the nail matrix, leaving the nail plate either for application of split skin graft or for spontaneous fibrosis.

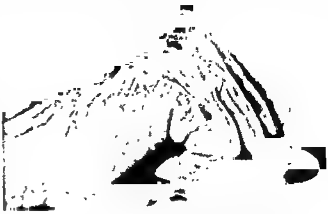


FIG. 5. This is the hand in full flexion with minimal blanching at the knuckle joints and good flexion in all the interphalangeal joints.

PREVENTIVE MEASURES

Familiarity with these deformities makes the surgeon aware of certain preventive measures that may be taken early in order to avoid extensive surgery. Early adequate wound excision allows production of a healthy granulating wound receptive for a skin graft. Flexion of the knuckle joints and flexion of the interphalangeal joints should be accomplished before dorsal skin is applied, and these joints should be extended if the skin is applied on the volar surface. The web space should be held wide open and covered with skin as early as possible. The little finger should be adducted and flexed, and the skin graft applied to the lateral aspect of this digit in such a way as to prevent recurrence of contracture. The use of Kirschner wires is not advisable when there is an open granulating wound, but adequate plaster splinting may be utilized in order to keep all joints in the correct position while the skin is maturing. Early active motion of the digits should be utilized as soon as the skin graft has healed. A dorsal splint, changed frequently, is the simplest method of maintaining full flexion following skin-grafting and while the skin matures. A molded palmar splint, changed when necessary, will prevent flexion deformities if a palmar burn is not too deep. A separate splint to maintain the thumb web space is imperative.

Fig. 4 (*Continued from facing page*)
graft was placed directly on the tendon sheaths and the digital nerves, and was carried far laterally in order to avoid longitudinal keloid. The finger was held in the corrected position with a Kirschner wire through the distal and the proximal interphalangeal joints. This wire was removed 10 days after its insertion. The *ring finger* has had a dorsal tenotomy for fixed extension contracture of the distal joint and a volar excision of fibrous tissue for the flexion contracture This digit also is maintained in the corrected position with a Kirschner wire, the distal joint being held in flexion and the proximal joint in extension. The little finger has had skin release and tenotomy at the distal end of the middle phalanx, followed by fixation with Kirschner wire and split skin graft applied to the dorsum.

(*Center, right*) Shows a method of skin-graft application. The silk sutures are long, and a pressure dressing is inserted directly over the graft and tied in place with the sutures.

(*Bottom, left*) Shows the fingertips held in the corrected position. The tip of the index finger is held in flexion and the tip of the long finger in extension, and the distal phalanges of the ring and the little fingers also are held in flexion.

(*Bottom, right*) This is the hand 9 months after surgery with adequate correction of all contractures and considerable improvement in function. Again, yearly observation is necessary in order to treat the possible recurrent contracture on the flexor surface. The mild mallet deformity of the index is of no significance.

FIG. 6. Shows residual burns from an open fire that burned this child's clothes. The face was protected partially by the hands, and the dorsal burns occurred. (*Left*) The hand shows severe keloid formation with moderate limitation of flexion at the knuckle joints and prolongation of the skin at the webs that prevented spreading of the digits. The index finger was limited in flexion at the interphalangeal joints, and the remaining lateral digits were severely limited in extension at the proximal joints and in flexion at the distal joints. The thumb web was contracted moderately (*Right*) The hand shows more severe injury, with greater damage to the proximal and the distal joints, all of which were in firm, fixed flexion. Adequate skin replacement and joint arthrodesis of all interphalangeal joints were necessary for the right hand. For the left hand, skin replacement, arthrodesis of the proximal joints of the lateral three digits and soft-tissue release for the index finger allowed satisfactory function. The original skin graft, applied following early wound excision, may have to be excised in a couple of years in the growing child, or even the adult, in order to allow full motion and healthier skin coverage. Abdominal flaps usually are not necessary if the tendons are intact.

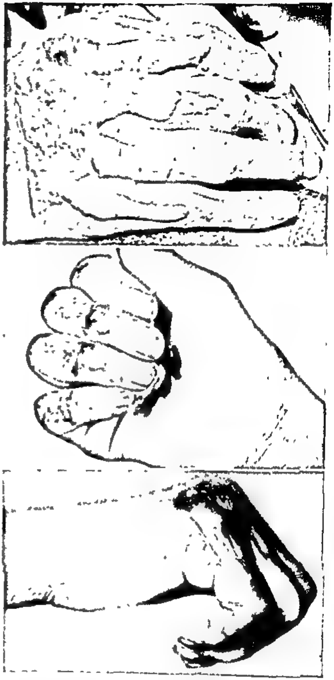
GROUP 2—BURN AFFECTING SKIN, TENDONS AND LIGAMENTS

Reconstructive surgery of the hands included in this group may require skin replacement, tenolysis of common extensor tendons, release of dorsal hood covering the metacarpophalangeal joints and excision of the dorsal and volar capsule and collateral ligaments. Figure 7, *top*, is an operating-room view of a hand with the digits contracted in full extension. There was 5° of motion at the knuckle joints and 10° at the proximal interphalangeal joints. The patient could not grasp large or small objects and could use the hand only as a steadying mechanism. Unfortunately, the initial treatment had included immobilization of the hand on a board splint with the digits in full extension and the thumb web narrowed. In addition, several weeks passed before a split skin graft was applied, and the graft was used only to fill in unhealed areas where keloid had not occurred. Several months of physical therapy had been attempted without improvement of the stiffened joints. The major deformities might have been avoided if the original dressings had been applied with the digits in flexion, if the position of function had been utilized during immobilization and if adequate early excision of necrotic tissue had been followed by early placement of split skin grafts.

METACARPOPHALANGEAL JOINT CONTRACTURE

Surgery necessary for improvement of hand function (Fig. 7, *left*) included excision of the dorsal skin with the distal margins extending past the metacarpophalangeal joints and into all the web spaces. Tenolysis of the extensor tendons was done where necessary, and the extensor hood over the knuckle joints was elevated gently by blunt

FIG. 7. (*Top*) This is the operative appearance of a hand that had severe limitation of motion at the knuckle joints, the proximal interphalangeal joints and the distal finger joints. Adequate excision of keloid and deep fibrosis was necessary, and, as usual, the skin excision had to be carried across all joints that showed limitation of motion or severe blanching of the skin when flexion was attempted. At the knuckle joints it was necessary to excise the collateral ligaments and release the dorsal and the volar capsules. The extensor tendons were lengthened over the proximal phalanges, and the collateral ligaments were excised from the proximal interphalangeal joints. Tenotomies were done at the middle phalanges in order to allow increased flexion of each fingertip. The lateral bands of the intrinsic muscles were removed from each of the digits, leaving only the transverse fibers at the level of the knuckle joints. Kirschner-wire fixation was utilized in order to hold the proximal joints in firm flexion, to keep the distal joints flexed, and to allow adequate stability while new skin was applied with the joints in a full corrected position. (*Center and bottom*) Show the hand postoperatively with improved flexion. Adequate extension was possible with increased function. Arthrodesis of the interphalangeal joints was not necessary, but occasionally it has to be done on selective digits if contracture recurs.



and sharp dissection without actual destruction of any of its fibers. Extension contracture of these joints was corrected by careful excision of the collateral ligaments and release of the dorsal and volar capsule. The collateral ligaments were exposed through a horizontal incision 3 mm. long made through the deep fascia and the extensor retinaculum in the mid-lateral area, directly over the joint space The extensor hood was separated from the deeper structures by gentle blunt dissection and an incision was then made into the joint The collateral ligaments were identified and excised carefully, leaving as much of the interosseous tendon as possible. A small curved blunt dissector was inserted into the joint, traction was applied to the finger, and the dissector was used to free the volar ligament from the metacarpal head. A similar incision was made on the ulnar side of the joint, and the same procedure was done. Flexion of the proximal phalanx then was attempted without force. If adequate flexion through at least 60° is not obtained, the dorsal capsule is released from its bony insertion at the level of the metacarpophalangeal joint. Usually this allows additional flexion to almost 90°. A fine Kirschner wire next is inserted through

FIGS. 8 and 9 present same case Fig. 8 (*Above*). (*Top, left*) The contractures in the proximal and the distal joints are the indirect result of generalized thermal injury with no actual local burn. There was moderate limitation of extension at the metacarpophalangeal joints due to intrinsic muscle contracture. The hyperextension deformity at the proximal interphalangeal joints was severe and would allow only a few degrees of flexion when the digits were in full flexion. However, the proximal joints were resilient, and the articular cartilages were found to be in healthy condition when the joints were exposed. Each joint was explored through a dorsal oblique incision, and the necessary tissue contracture was corrected without resorting to arthrodesis. Usually it is not possible to determine the extent of treatment necessary until the tissues are examined at surgery.

(*Top, right*) Shows the severed lateral intrinsic band held in the thumb forcep. There is an incision in the retinaculum over the proximal joint. The central slip of the extensor tendon can be indentified covering the proximal joint. Following excision of the lateral band and the oblique fibers, improved, but not full, flexion occurred. Therefore, it was necessary to open the joint.

(*Bottom, left*) Shows the reflected retinaculum of the extensor mechanism with a probe under the collateral ligaments and resting on the volar capsule. The collateral ligaments were excised from both the radial and the ulnar sides, utilizing the same skin incision and the same incision through the retinaculum.

(*Bottom, right*) Shows the extensor hood being pulled back into place after the dorsal capsule had been severed from its attachment to the distal end of the proximal phalanx The ulnar collateral ligament has been excised, the radial collateral ligament removed and the volar capsule pushed out of the joint, and a piece of Gelfoam is being inserted under the extensor tendon from within the joint. A step-cut lengthening of the extensor tendon over the proximal phalanx frequently is necessary to obtain final flexion to 90°. A Kirschner wire next was inserted through the joint, being allowed to extend out through the skin. This was used to hold the finger in flexion for about 10 to 12 days.

the metacarpal neck, across the joint and into the entire length of the proximal phalanx. Pins are removed in 10 days, a dorsal plaster splint is substituted at night, and active motion is allowed part time each day. Several weeks of splinting and exercise may be necessary before the patient can actively extend the digits to a straight line. Occasionally there develops at the knuckle joints a mild permanent flexion deformity that usually is no handicap.

Proximal Interphalangeal Joint Contracture

This may occur in extension or in flexion. If the extension contracture is rubbery, if the skin is loose and abundant, if there is no adherence of skin to bone and no destruction of the extensor tendon and lateral band mechanism, it is likely that this joint can be mobilized by tendon and ligament release and tendon lengthening. Figure 8, *top, left,* shows fixed deformities and contractures that occurred while the patient was being treated for extensive back, abdomen, arm and thigh burns. Adequate splinting was not possible early, and, at a later time, the contractures were fixed in such a way as to prevent the splints alone from correcting the deformity. Flexion of the proximal interphalangeal joints was limited, with the fingers in any position, due to contracture of the extensor tendon, the dorsal capsule, the collateral ligaments and the intrinsic lateral band mechanism. There was adequate skin that did not require replacement.

The decision rested between arthrodesis and mobilization, and, as usual, it was not possible to determine which was necessary until the joints were exposed. The finger was opened through an oblique dorsal incision extending from the distal radial aspect to the proximal ulnar area through the length of the finger. Figure 8, *top, right,* shows the appearance of the central slip of the extensor mechanism and the procedure required for mobilization of the joint. The radial and the ulnar lateral bands were excised, leaving the transverse proximal fibers. This allowed increase in flexion of about 10°. The central slip of the extensor tendon over the proximal phalanx was released from its periosteal attachment, and this allowed an additional 5° of flexion. The retinaculum opposite the proximal interphalangeal joint was opened through a vertical incision, and the volar and the dorsal expansions were detached carefully from the deeper collateral ligaments (Fig. 8, *bottom, left*). The radial collateral ligament was excised, and the volar plate was released partially from its proximal phalangeal attachments but not destroyed. The dorsal capsule was detached from the distal end of the proximal phalanx, and this allowed additional, but not complete, flexion. The extensor mechanism then was reflected toward the ulnar side of the finger, and the ulnar collateral ligament was excised without making an incision in the superficial retinaculum (Fig. 8, *bottom, left*). However, not until the central slip of the extensor mechanism over the middle phalanx was lengthened by Z-plasty was it possible finally to obtain 90° of flexion. The retinaculum and the extensor tendon next were

Fig. 9. Shows the hand postoperatively with improved flexion at the proximal joints but not normal full flexion. The greatest improvement was noted when the knuckle joints were in extension, and in this position the proximal joints could be flexed to almost 90°.

repaired by interrupted fine silk sutures, and a fine Kirschner wire was inserted through the distal end of the proximal phalanx across the proximal joint into the middle phalanx. The hand was immobilized with the knuckle joints toward extension and the interphalangeal joints in flexion. This allowed a stretch of the intrinsic mechanism and increased the grasp by allowing greater clearance of the fingers from the palm. The postoperative result is seen in Figure 9.

Moderate flexion deformity of the proximal interphalangeal joint (buttonhole) may be associated with extension contracture at the distal interphalangeal joint. This results from direct injury to the skin and the dorsal capsule over the proximal joint and displacement of the lateral bands toward the volar aspect of the finger. The lateral bands then act as extensors of the distal phalanx and flexors of the proximal phalanx, and prevent flexion of the distal joint. Repair of the extensor mechanism at the proximal joint may not be necessary in order to obtain correction. Figure 4, *top, left* (ring finger), shows the digit prior to tenotomy at the level of the middle phalanx. Tenotomy is done as a step-cut lengthening, and the tendinous attachment at the distal joint is elevated completely without interfering with skin coverage. The joint is opened, if necessary, in order to attain adequate flexion. After the lateral bands are loosened and the distal joint is flexed, it is possible usually to extend the proximal interphalangeal joint to a straight line. Pin fixation will hold the distal phalanx in fixed flexion (Fig. 4, *bottom, left*), and the proximal phalanx in a straight line, and allow a firm base for insertion of a split skin graft over the area of tenotomy and over the joints if necessary. Even though this graft is placed directly on bone or tendon, it usually heals. Figure 4, *bottom, right*, shows the postoperative result that has allowed conversion of one deformity to another by tenotomy. A mallet-finger position allows greater flexion and increased function.

Flexion Contracture of the Digit

This contracture, due to volar scar, requires scar excision, using both horizontal and vertical incisions, isolation of the digital nerves, release of the volar capsule if necessary, followed by fixation with Kirschner wire and application of split skin graft held in place with silk ties (Fig. 4, *center, right*). The graft matures, even if placed on digital nerves and flexor tendon sheaths. If the contracture is old and severe, it may be impossible to obtain full correction at the first operation because of the danger of spasm in the digital arteries and nerve stretch. Maximum correction is attained within the limits of safety, and a second procedure is planned for the appropriate time. Furthermore, bone growth in children may cause recurrence of contracture if fibrosis is present, and, occasionally, replacement of skin and scar may be necessary.

A thumb contracture on the volar aspect of the palm usually is corrected by adequate excision of skin and palmar fascia with incisions placed in such a way as to eliminate keloid, which tends to cause recurrence of the contracture. Figures 2 and 3 show two palmar contractures in children, both of which required extensive removal of skin and replacement by split skin graft on three different occasions over a 2-year period. It was difficult to control recurrence because of severity of the initial contracture, peripheral keloid and growth factors

GROUP 3—BURN AFFECTING SOFT TISSUE, BONE AND JOINTS

Severe burns will result in destruction of skin, tendon, periarticular ligaments and articular surfaces. It is difficult to prevent contractures that occur following such burns. In most instances they preclude the possibility of mobilization of joints, and usually they require arthrodesis, amputation or partial or complete joint excision. Figure 10, *top*, shows severe flexion deformities of the proximal finger joints that resulted from complete

FIG. 10. (*Top*) This is the resulting deformity following a severe dorsal burn involving skin, tendons, ligaments and articular cartilages of the lateral three digits. The index finger was limited in flexion at the proximal and the distal joints. There is good flexion and extension at the knuckle joints, but the web spaces are narrowed because of prolongation of keloid. The thin skin on the dorsum of the proximal joints and the damage to the cartilage make reconstruction obtaining motion difficult. (*Center*) Shows the hand following arthrodesis of the proximal and the distal joints of the little finger and the proximal joints of the ring and the long fingers through dorsal incisions. The digits can be brought away from the palm because of adequate range of motion in the knuckle joints. At a later date, skin grafts were inserted between the webs in order to improve lateral and medial motion. The collateral ligaments and the extensor tendon were released in the proximal joint of the index finger. (*Bottom*) Shows the extent of grasp. The patient now is able to handle a glass, and the hand is functional for holding large objects. Pinch and hook also are possible because of the normal motion of the thumb and improved motion of the index finger.

destruction of the extensor mechanism and articular surfaces. Three of the digits of the hand were in excessive flexion and prevented the patient from holding a glass or grasping even smaller-sized objects. The digits were poorly placed and painful, and they were not satisfactory even as a hook. Acute flexion of the proximal joint frequently is accompanied by excessive flexion of the distal joint due to overpull of the flexor digitorum profundus and damage to the extensor mechanism. Improvement occurs following arthrodesis of the proximal interphalangeal joint in 50° of flexion and arthrodesis of the distal interphalangeal joint in about 15° of flexion (Fig. 10, *center*). This stabilizes both areas and allows a satisfactory digit for grasping and holding. A dorsal oblique incision was utilized in exposing both the proximal and the distal joints. The extensor mechanism was scarred and partially absent, and what was left of it was retracted so that the fibrous tissue and remaining joint cartilage could be resected with a sharp osteotome, while the finger was stabilized on an anvil. The volar ligament was left intact to aid the final fixation. Both phalanges were cut back to cancellous bone, leaving as wide a surface area as possible. Usually mortising is not necessary when arthrodesing a flexion deformity. In this instance the distal interphalangeal joint also was opened, and adequate bone and cartilage were removed to allow extension of the tip to a position of 165°. Similar procedures were done on the ring and the little fingers, and the joint surgery was completed before any of the pins and the chip grafts were inserted. In this way, proper

FIG. 11. (*Top*) This is the opposite hand of that illustrated in Figures 8 and 9. No direct burn occurred to this hand, but the contractures were fixed and severe. There was no resiliency in the proximal joints. Extension at the knuckle joints was limited. There was no active flexion at the proximal joints (*Center*) Shows the method of arthrodesis utilized on 4 digits. Restoration of motion was not possible because of the severe adhesions between the soft tissue and the joint and because of the degeneration of the cartilage secondary to prolonged hyperextension and compression. Arthrodesis from extension to flexion is considerably more difficult, and bone union takes a longer time than does fusion from flexion to extension. Fine Kirschner wires are used to hold the bone ends, which are carefully shaped and mortised Small bone fragments are packed around the area of fusion. The lateral bands, which are held in the clamps, are resected in order to allow greater extension at the metacarpophalangeal joints. Nothing was done to the fingertip joints. (*Bottom*) Postoperatively the hand shows adequate flexion. Improved extension was present, greater strength existed, and there was a better grasp of large objects. However, this hand was not as satisfactory as the opposite one, in which motion in the proximal joints was maintained.

alignment, particularly rotation, was determined. Gentian violet was used to mark the palm at the point where each fingertip would touch when flexed, and this alignment was maintained while three or four crossed Kirschner wires were inserted, both of which were placed just under the lateral border of the fingernail in order to prevent contusion. The index finger (Fig. 10, *center*) had a mild extension contracture. The joint was explored, and the articular cartilage and the extensor mechanism were found to be intact. The collateral ligaments were excised, the extensor mechanism was freed of adhesions, and the digit was mobilized rather than fused.

Arthrodesis from extension to flexion (Fig. 11) is more difficult of accomplishment and requires a longer healing time for fusion to occur. In this instance there was no skin contracture, but hyperextension was present at the proximal interphalangeal joints as the result of contracture of the intrinsic muscles of the hand, as well as long-standing contracture of the collateral ligaments at the proximal interphalangeal joints and persistent pull of the flexor profundus on the fingertips. Exploration of the joints through oblique, dorsal incisions indicated that the extensor mechanism had been severely damaged and was strongly adherent to the dorsum of the joint. The articular cartilages were rough, worn and fibrotic. Mobilization was not possible. The ends of

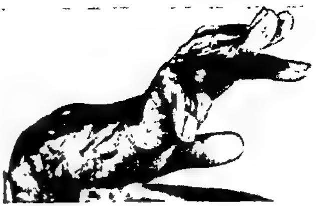


FIG. 12. (*Top*) This is a severely deformed hand several months following deep local burn to the dorsum of the hand and the dorsum of all the digits. The little finger had an irreparable extension contracture at the knuckle joint and flexion deformity at the proximal joint. The joints were badly damaged. Sensation was good on the volar surface. The ring finger showed hyperextension at the distal joint, due to skin and tendon contracture, as well as joint change and irreparable change at the proximal joint with severe hyperextension deformity at the knuckle joint. The long finger showed the same deformity. The index finger was fixed in extension at the knuckle joint but had fairly good motion at the proximal joint. It was necessary to remove all the skin from the dorsum of the hand and the digits. Soft-tissue release was not possible, and removal of the metacarpal heads of the long and the ring fingers was accomplished. The little finger was amputated, along with its metacarpal, and arthrodesis of the proximal and the distal joints of the long and the ring fingers was accomplished. New skin was used to cover the fingers and the back of the hand, with the digits placed in full flexion at the knuckle joints. The thumb web was opened by skin excision, fasciotomy and partial myotomy. (*Bottom*) This is the hand several months after surgery. The filleted flap from the little finger has been folded over the knuckle joint of the ring finger. Range of motion in the lateral 2 digits improved but totaled only about 25°. However, grasp, pinch and hook were improved, and there was fairly good wrist motion.

the phalanges were cut back, and the digits were shortened moderately. Mortising between the proximal end of the middle phalanx and the distal end of the proximal phalanx was necessary in order to get good bone contact. Fixation with Kirschner wires held the fragments firmly, and small bone chips were packed in the crevices. The final degree of flexion of the finger is determined by the occupation of the patient and by the range of motion at the knuckle joints. If he must handle large objects, such as sacks or barrels, the digit is fixed toward extension. If hyperextension is possible at the knuckle joints, more flexion can be allowed in the final position for arthrodesis.

Metacarpal head resection may be necessary if hyperextension deformity at the metacarpophalangeal joints is old and will not respond to the usual procedures of skin release, tenolysis and collateral ligament excision. Figure 12, *top*, shows the hand prior to surgery with nonfunctioning ring and little fingers. Resection of the second and the third metacarpal heads allowed the phalanges to be taken down to neutral or slight flexion, and this increased their efficiency after other procedures were done to improve grasping. Arthrodesis of the knuckle joints was considered, but, with limitation of motion in the interphalangeal joints, it is not advisable to stiffen the metacarpophalangeal joints.

Partial or complete carpalectomy occasionally is necessary when skin and joint contracture has been present for long periods. The patient, who had severe burns, following which the hands were in the flexed

position for almost 2 years before active reconstruction was started, required dorsal carpalectomy with removal of the navicular, the lunate, the triangularis, the greater multangular, the lesser multangular and the capitate. This allowed the hands to come up to 180° but no farther. In order to increase the range of dorsiflexion, a transverse incision was made on the volar aspect of the wrist, and tendon lengthening of the wrist flexors was done. The hand then could be brought up an additional 25°. The skin defect that resulted on the volar surface was replaced by a split graft.

Amputation of part of a digit or of an entire ray may be the best way to improve general use of the hand. Fingertip removal, amputation through the interphalangeal joints or ray deletion may eliminate a useless segment and allow improvement in the same or adjacent digits.

SUMMARY

Reconstructive surgery of the burned hand has been described in detail. The treatment selected for deformity of skin, tendon, ligaments, joints and bone depends on the severity and the extent of the injury.

BIBLIOGRAPHY

Braithwaite, F., Channel, G. D., Moore, F. T., and Whillis, J.: The anatomy and function of the extensor complex, Brit. J. Plast. Surg 2:175-187, 1949.

Braithwaite, F., and Watson, J.: Some observations on the treatment of the dorsal burn of the hand, Brit. J. Plast. Surg. 2:21-31, 1949.

Bunnell, Sterling, Doherty, E. W., and Curtis, R. M.: Ischemic contracture, local, in hand, Plast. & Reconstruct. Surg. 3:424-432, 1948.

Curtis, R. M.: Capsulectomy of the interphalangeal joints of the fingers, J. Bone & Joint Surg. 36A:1219-1231, 1954.

Goldner, J. L.: Deformities of the hand incidental to pathological changes of the extensor and intrinsic muscle mechanisms, J. Bone & Joint Surg 35A:115-131, 1953.

Steindler, A.: Arthritic deformities of the wrist and fingers, J. Bone & Joint Surg 33A:849-862, 1951.

Chirurgia Reconstructive del Mano post Vulneration Thermal

Summario in Interlingua

Le severitate e le extension del arditura original del mano determina in parte le magnitude del deformitate residue. Inecessari deformitates additional pote resultar ab retardo del recopertura cutanee, ab malposition digital, ab le non-intendite clausion in le area del membranas interdigital, e ab le immobilisation excessive del digitos.

Il es rar que solmente un typo specific de histo es afficite in arditura de grado sever. Le typos de histo que pote esser afficite—sol o in combination—es (1) pelle e fascias superficial, dorsal tendines extensori commun, vainas tendinal, e fascias profunde, (3) cappotta extensori, capsula dorsal e volar, e ligamentos collateral del articulationes metacarpophalangee, (4) tendine extensori e cappotta dorsal, capsula dorsal e volar, e ligamentos collateral del proximal e distal articulationes phalangee, (5) bandas lateral digital del musculos intrinsec, (6) musculos intrinsec del mano, (7) histos palmar comparabile a structuras dorsal—fascias cutanee, tendines, e capsula, e (8) superficies articular del articulationes manual e digital.

In planar le tractamento, le arditruras pote esser dividite in tres gruppos: (1) Arditruras que affice le pelle e le fascias superficial, (2) arditruras que affice pelle, fascia, tendines, e ligamentos directe- o indirectemente, e (3) vulneres de histos molle insimul con lesion de osso o articulation.

Le tractamento pote includer un adequate reimplaciamento per lamina o pediculo de pelle insimul con excision de fibrosis excessive del fascia dorsal o volar. In plus, teno-

lysis, tenotomia, e excision del ligamentos collateral del articulationes metacarpophalangee e interphalangee pote esser necessari. In plus sever situationes, arthroplastia del articulationes metacarpophalangee, selective fusiones articular, e mesmo amputationes es possibilemente inevitabile.

Fixation intra-articular per filo de Kirschner e le uso postoperatori de adequate apparatos de supporto es extrememente importante. Post le appropriate periodo de immobilisation e de supporto corrective, exercitios active resulta usualmente in meliorate function.

10

Salvage of the Injured Distal Phalanx*

Plan of Care and Analysis of 369 Cases

WILLIAM METCALF, M.D.,† AND WILLIAM P. WHALEN, M.D.‡

INTRODUCTION

The rationale of treatment and the principles of rehabilitation in serious injury or infection of the hand have been well publicized and taught purposefully. The same does not appear to hold true of the relatively minor injuries of the hand, particularly those of the distal phalanx. Treatment of these has been found to range from casual suturing or attempted reconstruction in the physician's office to the formal, almost ritualistic, procedure in a major operating room. The following results of misguided or overzealous efforts in these cases have been observed: Loss of a distal phalanx following a simple deep laceration; scarred and painful pads following exploration for removal of harmless foreign bodies; and stiff or painful fingers following application of pedicle flaps, when local repair might have sufficed. It is also felt that large numbers of injured distal phalanges are being sacrificed for lack of appreciation of the possibilities of salvage by reconstruction, and perhaps even for reasons of expedience.

In a relatively large series of hand injuries, a majority of which were limited to the distal phalanges, a certain pattern of care for the latter was evolved. The over-all plan included the treatment of practically all patients on an ambulatory basis, the use of an emergency suite minor operating room, digital nerve block anesthesia, avoidance of the use of a tourniquet, and omission of the administration of antibiotics.

This plan deviated in many respects from the now traditional one in hand surgery, which has as its basic features hospitalization of the patient, use of a major operating room, administration of general anesthesia, use of a tourniquet and administration of antibiotics. To determine whether or not such deviation was warranted and to document the efficacy of the plan of care adopted, an analysis of the clinical results in the cases treated serially over the past 7 years was undertaken. Morbidity and disability data were also analyzed for intra-series comparisons or for comparison with those in which other plans of care were utilized.

MATERIAL

The material analyzed comprised 369 cases with compound injury to one or more distal phalanges. Included were those with partial or complete amputation, avulsion of soft tissue comprising the tactile pad, bursting laceration with multiple flap formation, crushing injury with avulsion of soft tissue and bone, avulsion or rupture of the nail base or matrix with exposure of the bone, or

* From the Departments of Surgery of St. Vincents Hospital and the Bronx Municipal Hospital Center, New York

† Associate Professor of Surgery, Albert Einstein College of Medicine, New York.

‡ Chief of Plastic Surgery, St. Vincents Hospital, New York

TABLE 1. INJURY-PRODUCING AGENTS

Machine Powered	No.	%	Man Powered	No.	%
Machine works	85	24.4	Heavy object	31	8.9
Power press	82	23.5	Door	25	7.2
Cutting machine	46	13.2	Knife	21	6.0
Power saw	25	7.2	Block tackle	10	2.9
Printing press	19	5.5	Hand truck	4	1.2
Total	257	73.8	Total	91	26.2

any combination of these. Excluded from consideration were those with simple laceration, closed fracture of the distal phalanx, rupture of the extensor tendon, simple avulsion of the nail, etc.

Of the injuries, 74 per cent were caused by power machinery; 26 per cent by "man-powered" tools and objects such as doors, knives, heavy objects, etc. One quarter of this group, 7 per cent of the total, were caused by doors of buildings, elevators and automobiles (Table 1).

The anatomic and the numerical distributions of the single and the multiple phalangeal injuries are indicated. There were 281 cases with a single phalangeal injury and 78 with multiple injuries, 54 with two, 23 with three, and 1 with four. In the single injuries the index finger was involved twice as often as any of the others, and in the multiple injuries the index, the long and the ring fingers were involved most frequently. There was a moderate left to right preponderance (Table 2).

TABLE 2. ANATOMIC DISTRIBUTION

	Right	Left	Total	%
Single Phalanx				
Finger				
1	30	27	57	15.8
2	44	60	104	28.9
3	29	32	61	17.0
4	13	19	32	8.9
5	15	12	27	7.5
Total	131	150	281	78.1
Multiple Phalanges				
Fingers				
1-2	2	0	2	0.6
2-3	11	7	18	5.0
3-4	8	20	28	7.7
4-5	3	2	5	1.4
2-4	1	0	1	0.3
1-2-3	0	1	1	0.3
2-3-4	3	7	10	2.8
3-4-5	7	5	12	3.3
1-3-4-5	1	0	1	0.3
	36	42	78	21.7
All Injuries				
Total	167	192	359	99 8

10

Salvage of the Injured Distal Phalanx*

Plan of Care and Analysis of 369 Cases

WILLIAM METCALF, M.D.,† AND WILLIAM P. WHALEN, M.D.‡

INTRODUCTION

The rationale of treatment and the principles of rehabilitation in serious injury or infection of the hand have been well publicized and taught purposefully. The same does not appear to hold true of the relatively minor injuries of the hand, particularly those of the distal phalanx. Treatment of these has been found to range from casual suturing or attempted reconstruction in the physician's office to the formal, almost ritualistic, procedure in a major operating room. The following results of misguided or overzealous efforts in these cases have been observed: Loss of a distal phalanx following a simple deep laceration; scarred and painful pads following exploration for removal of harmless foreign bodies; and stiff or painful fingers following application of pedicle flaps, when local repair might have sufficed. It is also felt that large numbers of injured distal phalanges are being sacrificed for lack of appreciation of the possibilities of salvage by reconstruction, and perhaps even for reasons of expedience.

In a relatively large series of hand injuries, a majority of which were limited to the distal phalanges, a certain pattern of care for the latter was evolved. The over-all plan included the treatment of practically all patients on an ambulatory basis, the use of an emergency suite minor operating room, digital nerve block anesthesia, avoidance of the use of a tourniquet, and omission of the administration of antibiotics.

This plan deviated in many respects from the now traditional one in hand surgery, which has as its basic features hospitalization of the patient, use of a major operating room, administration of general anesthesia, use of a tourniquet and administration of antibiotics. To determine whether or not such deviation was warranted and to document the efficacy of the plan of care adopted, an analysis of the clinical results in the cases treated serially over the past 7 years was undertaken. Morbidity and disability data were also analyzed for intra-series comparisons or for comparison with those in which other plans of care were utilized.

MATERIAL

The material analyzed comprised 369 cases with compound injury to one or more distal phalanges. Included were those with partial or complete amputation, avulsion of soft tissue comprising the tactile pad, bursting laceration with multiple flap formation, crushing injury with avulsion of soft tissue and bone, avulsion or rupture of the nail base or matrix with exposure of the bone, or

* From the Departments of Surgery of St Vincents Hospital and the Bronx Municipal Hospital Center, New York.

† Associate Professor of Surgery, Albert Einstein College of Medicine, New York.

‡ Chief of Plastic Surgery, St Vincents Hospital, New York.

TABLE 1. INJURY-PRODUCING AGENTS

Machine Powered	No.	%	Man Powered	No.	%
Machine works	85	24.4	Heavy object	31	8.9
Power press	82	23.5	Door	25	7.2
Cutting machine	46	13.2	Knife	21	6.0
Power saw	25	7.2	Block tackle	10	2.9
Printing press	19	5.5	Hand truck	4	1.2
Total	257	73.8	Total	91	26.2

any combination of these. Excluded from consideration were those with simple laceration, closed fracture of the distal phalanx, rupture of the extensor tendon, simple avulsion of the nail, etc.

Of the injuries, 74 per cent were caused by power machinery; 26 per cent by "man-powered" tools and objects such as doors, knives, heavy objects, etc. One quarter of this group, 7 per cent of the total, were caused by doors of buildings, elevators and automobiles (Table 1).

The anatomic and the numerical distributions of the single and the multiple phalangeal injuries are indicated. There were 281 cases with a single phalangeal injury and 78 with multiple injuries, 54 with two, 23 with three, and 1 with four. In the single injuries the index finger was involved twice as often as any of the others, and in the multiple injuries the index, the long and the ring fingers were involved most frequently. There was a moderate left to right preponderance (Table 2).

TABLE 2. ANATOMIC DISTRIBUTION

	Right	Left	Total	%
Single Phalanx				
Finger				
1	30	27	57	15.8
2	44	60	104	28.9
3	29	32	61	17.0
4	13	19	32	8.9
5	15	12	27	7.5
Total	131	150	281	78.1
Multiple Phalanges				
Fingers				
1-2	2	0	2	0.6
2-3	11	7	18	5.0
3-4	8	20	28	7.7
4-5	3	2	5	1.4
2-4	1	0	1	0.3
1-2-3	0	1	1	0.3
2-3-4	3	7	10	2.8
3-4-5	7	5	12	3.3
1-3-4-5	1	0	1	0.3
	36	42	78	21.7
All Injuries				
Total	167	192	359	99.8

In the emergency room the patient's injured hand was soaked for 15 minutes in a sterile container of normal saline to which a few cubic centimeters of pHisohex had been added. Tetanus antitoxin or toxoid was given as indicated. The emotional patients and those with multiple phalangeal injury were given Demerol or Nembutal.

In the emergency suite operating room, with the surgeon masked, gloved and gowned, the injured extremity was prepared from the fingertips to above the elbow and draped. Then the finger was anesthetized, the injection being made at both ends of the anterior quadrant at the level of the proximal flexion crease. The hypodermic needle (No. 25), held about 30° from the perpendicular, was introduced almost to the bone, and from 1½ to 2 cc. of 1 per cent procaine was injected at each site. Circumferential injection was not used. (A point of anatomy usually unappreciated is that the dorsal aspect of the distal two phalanges derives its sensory supply from branches of the *volar* digital nerves. Therefore, volar block of each proper nerve gives anesthesia of the dorsum of the distal two phalanges.) The effectiveness of the anesthesia was increased measurably by the stratagem of not overtly quizzing or testing the patient for the presence or the absence of pain. After a wait of 5 minutes the proximal edge of the wound was pinched with a thumb forceps. If the patient did not blink or wince, the procedure was started. Very occasionally a second block of one or both digital nerves was necessary. In the multiple injuries the nerves of the individual fingers were blocked successively as they were repaired. In the 350 cases so treated, resort to general anesthesia never was required. Of course, it was used in the few infants and children.

A tourniquet to the arm was not used. In the rare case where bleeding from the bone end or a retracted vessel interfered with the repair or the application of the graft, it was controlled by twisting a 4 x 8 inch gauze square folded to a 1-inch width around the base of the finger and holding it with a hemostat for a few minutes.

The general principles of saving as much tissue (and finger length) as possible, and of converting all open wounds into closed wounds, were always followed. Gentle technic was axiomatic and was further ensured by the use of fine instruments—No. 15 scalpel blade, small scissors, "mosquito" hemostats, Adson forceps, plastic needle holder and needles, and a small rongeur. Silk 5-0 was used for all ligatures and sutures; catgut was not used.

The wounds were irrigated freely with normal saline and débrided of all loose bits of tissue, shreds of epidermis and keratin. The skin edges were not trimmed, even if they were irregular; this was done only if they were badly crushed. The palpable fragments of bone still attached to the inner aspects of the pulp were dissected out. Vessels and nerves presenting in the wound were ligated as far proximally as possible. When the bone had to be trimmed, it was first coned out to avoid crushing the soft tissue. The nail base and the matrix being preserved were freed from the bone by insinuating the scalpel between them and sweeping it to and fro; the pulp was freed from the bone to be sacrificed by dissection at the level of the periosteum. After the reconstruction the defect remaining was covered with a split-thickness graft. This was taken from the upper medial aspect of the forearm (originally prepared and draped), or from the lateral thigh within the bathing-trunk area. The skin in the area chosen was infiltrated with procaine, a wheal being raised half again as large as the defect to be covered. A medium to thick split graft was cut, using one half of a double-edged razor blade held in a hemostat. The graft then was applied with interrupted sutures left long and a fitted gauze stent tied snugly over it.

The whole finger next was encased in a dressing using two, lengthwise triply folded, 4 x 8 inch gauze pads, at right angles to each other, one covering the sides and the

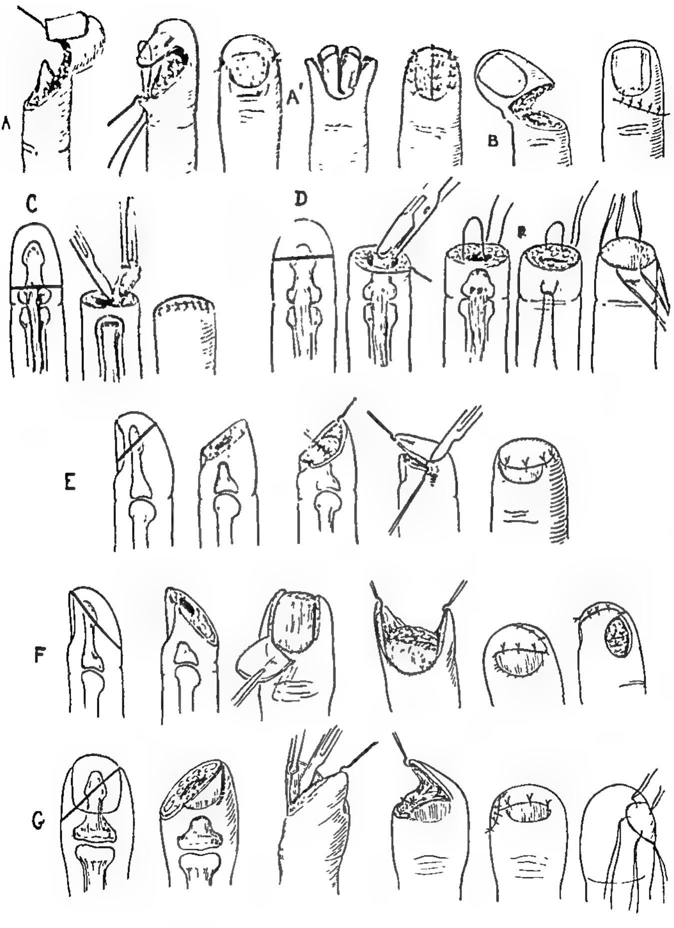


FIG. 1. See text.

other the front and the back of the finger. Compression then was effected by wrapping the dressing with roller gauze and adhesive tape. With this dressing there was singularly little pain, little to no maceration, and no swelling. Each patient was given a sling to wear. The dressing was not removed until the fifth to the seventh day in those with grafts and not until the tenth to the twelfth day in those with direct repairs.

SPECIFIC TYPES OF INJURY AND SCHEMES OF REPAIR

The phalangeal injuries could be classified into eight general types. The schemes of repair that allowed maximum salvage in each are outlined below and indicated in the diagrams.

No Tissue Loss

Crush Injury

In many such injuries multiple flaps of skin and nail base were formed, occasionally as many as five or six, and the bone was crushed or exposed. Minimal but careful débridement of the edges of the flaps and judicious shortening of the bone allowed reapproximation of the flaps without tension and reconstitution of a badly damaged distal phalanx (Fig. 1, A′).

Avulsion Injury

1. When the whole or part of the nail base and the matrix in continuity with the pad was avulsed as a flap, exposing the bone but hinged on enough volar or lateral skin to ensure viability, the whole flap was replaced over the bone, and the nail base or the matrix was reset in its normal position (Fig. 1, A).

2. When there was sharp amputation of the distal phalanx through as much as four fifths of the diameter, including the shaft of the bony phalanx, but with enough skin or a neurovascular pedicle to ensure viability, the whole was replaced and sutured carefully. The compression dressing acted as a molded splint, and wire fixation of the bone was not found to be necessary (Fig. 1, B).

Tissue Loss

Complete Amputation

When the distal phalanx was crushed irreparably or amputated sharply proximal to the eponychial fold and/or the insertion of the profundus tendon, the amputation was completed by removing the base of the distal phalanx, rongeuring off the condyles of the middle phalanx and fashioning flaps to close the finger end (Fig. 1, C).

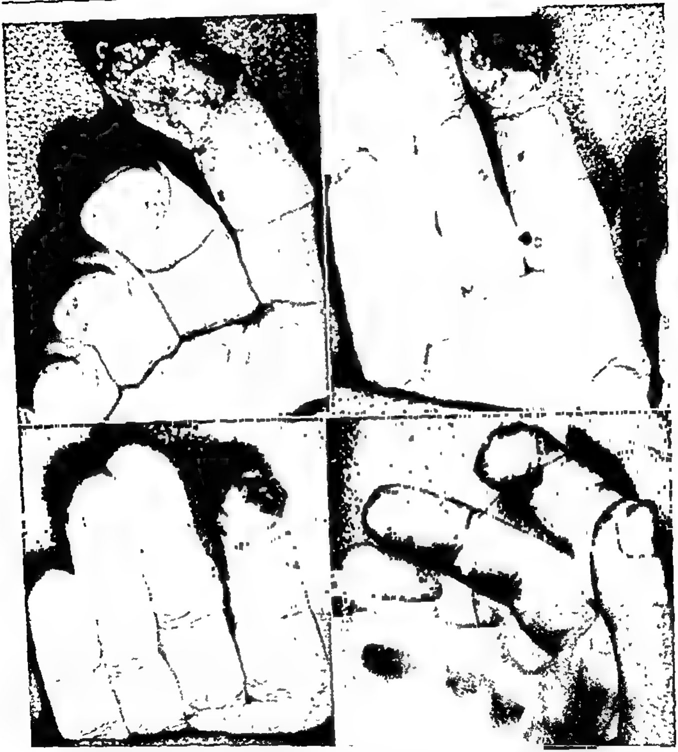
Partial Amputations

Transverse. If the proximal *third* of the distal phalanx remained, including insertion of the flexor profundus tendon, only enough bone was removed (usually 3-5 mm.) to allow approximation over the remaining bone of lappets of subcutaneous tissue as a soft base for the graft. If enough lateral or volar skin remained, direct repair without a graft preferably was carried out (Fig. 1, D).

Dorsal Oblique. When the nail and a portion of nail base, including varying amounts of the tuft and the shaft, were amputated, the bone was trimmed, and the remaining pad was turned backward and sutured to the remaining nail base. The contour of the pad was restored by removing a 3-mm. wedge at either side of the flap at its paronychial junction to avoid the formation of "dog ears" (Fig. 1, E).

Volar Oblique. When a greater portion or all of the pad was sheared off exposing the volar aspect of the tuft, the bone was rongeured off to the level of the proximal edge of the defect. The remaining lateral and medial portions of skin were formed into flaps by incisions in each paronychial fold. These flaps then were brought together over the bone end and sutured to each other and to the distal edge of the nail base, which was shortened appropriately. The remaining defect was covered with a graft (Fig. 1, F).

Lateral Oblique. In these diagonal amputations the triangular bone remaining was rongeured back to give a flat end a few millimeters proximal to the defect. All the re-



FIGS. 2 and 3, same case. Fig. 2 (*Above*). (*Top, left*) Forty-year-old woman whose index finger got caught in a bottling machine. The distal phalanx was badly crushed. In ordinary circumstances it would probably have resulted in amputation. (*Top, right*) Careful débridement of only irreparably damaged tissue elements. This preserved enough tissue to make reconstruction possible. (*Bottom, left*) Approximation of the lateral flaps produced good coverage of the bone and reconstituted most of the finger pad. (*Bottom, right*) A free graft, taken from the upper medial aspect of the forearm, covered the remaining defect.

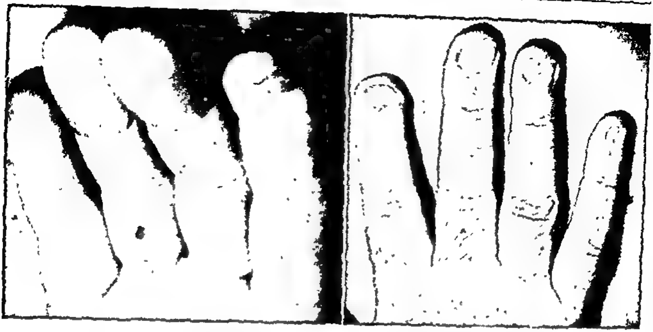


Fig. 3. (Top, left) Nine weeks after operation. *The graft has shrunk to about one half its original size. This contraction has further modeled the fingertip to its original contour. (Top, right) Dorsal view.* Normal-appearing distal phalanx with minimal loss of length. Regrowth of ap*parently normal nail. (Bottom) With sal*vage as the motive, it is astonishing how much tissue can be débrided and still leave enough for a *most satisfactory anatomic* and functional result.

maining skin opposite the defect was formed into a flap by incising it transversely at the nail-bed junction and proximally in the *paronychial fold. This flap then was brought* over the bone end reconstituting the pad. The remaining defect, usually about one third the size of the original, was covered with a graft (Fig 1, G).

In the schemes outlined above, palmar or cross-finger pedicle flaps were not mentioned. They were used only four times in this whole series for guillotine amputations *of the thumb and index finger just distal to the terminal joint. Here they were necessary* to preserve length that otherwise would have had to be sacrificed to achieve direct closure.

RESULTS

Anatomic and Functional Results

In the 369 cases *in this series,* 462 terminal phalanges were treated. Forty-five were amputated completely in the accident *or were crushed irreparably. It was possible* to salvage a functional distal phalanx in all the others by direct repair or reconstruction. In this group, 195 could be closed directly, and 222 had a *remaining defect requiring a graft.*

The primary healing was uneventful in over 97 per cent of the phalanges repaired, and the late complications were few. There *were three cases with infection* (0.71%); in *two, the grafts* were lost, but in none was there further loss of tissue. Grafts did not take in two other patients as a result of

Table 3. Morbidity Data

	Number	Hospital Days	Office Visits	Days Out of Work
Single phalanx, Total	285	124	1,838	6,976
Average		0.44	6.5	24.5
Multiple phalanges, Total	68	59	492	2,205
Average		0.7	7.2	32.4
Total	353	183	2,330	9,181
Average		0.52	6.6	26.0

hematoma formation. Very occasionally there was loss of a small flap (4-5 mm.) or a bit of tissue along a wound edge; there was no loss of any major flaps due to devascularization or gangrene. Five patients had moderately severe reactions to the tetanus antitoxin; three required hospitalization and corticoids for 3 to 4 days, and two had weakness of shoulder-group muscles for 6 to 8 weeks. Doubtless this was due to the recently recognized peripheral neuritis that occurs occasionally with tetanus antitoxin administration.

There were five late local complications. Two patients developed neuromata requiring excision; three required revision of their stumps—one with a tender exostosis, one with scar adherent to bone, and one with pain from an occluded bit of nail.

Morbidity and Disability Data

An indirect indication of the efficacy of the plan of care adopted were the results of the analysis of the morbidity and disability factors (Table 3).

There were only 183 hospitalization days for the whole group. Actually, most of these accrued during the first two years of the

Table 4. Rate of Return to Work

Week	Single No.	Single %	Single Cum. %	Multiple No.	Multiple %	Multiple Cum. %	Total No.	Total %	Total Cum. %
1	51	18.6	18.6	4	6.3	6.3	55	16.3	16.3
2	29	10.6	29.2	7	10.9	17.2	36	10.7	27.0
3	34	12.4	41.6	4	6.3	23.5	38	11.2	38.2
4	50	18.3	59.9	9	14.0	37.5	59	17.5	55.7
5	50	18.3	78.2	14	22.0	59.5	64	18.9	74.6
6	29	10.6	88.8	10	15.6	75.1	39	11.5	86.1
7	17	6.2	95.0	5	7.8	82.9	22	6.5	92.6
8	9	3.3	98.3	5	7.8	90.7	14	4.1	96.7
9	1	0.4	98.7	3	4.7	95.4	4	1.2	97.9
10	2	0.7	99.4	1	1.6	97.0	3	0.9	98.8
11	0	0.0	99.4	1	1.6	98.6	1	0.3	99.1
12	1	0.4	99.8	0	0.0	98.6	1	0.3	99.4
13	0	0.0	99.8	1	1.6	100.2	1	0.3	99.7
14	1	0.4	100.2	0	0.0	100.2	1	0.3	100.0
Total	274	100.2		64	100.2		338	100.0	

(*NOTE*. Any discrepancies between the various table totals and the total case figure of 369 is due to missing information.)

series. The emergency operating room was not available then, and all patients had to be admitted formally before treatment in the major operating-room suite. During the last 3 years of the series there were only 14 hospital days per year. The number of office visits per patient averaged 6.6 in the single injury and only 7.2 for those with multiple injuries.

The average time lost from work was 26.0 calendar days, or only 18 working days. The patients with single injury averaged 24.5 calendar days, and those with two or more phalanges injured averaged 32.4. Although not tabulated, a comparison of the results between those with direct repair and those who required a graft indicated no difference in the hospitalization figures, office visits or the days lost from work. Of course, all these factors were much higher in the four patients who required pedicle flaps.

The cumulative disability and rate of return to work are tabulated (Table 4). Fifty-five patients were back at work within the week of their injury, and of those 48 had returned within 3 days. In the over-all series, 55 per cent were back at work within the fourth week and 96.7 per cent within the eighth week! Only eleven patients returned after this period. These included some of the women patients who were psychologically disturbed by their injury, one of the patients with infection, two of the patients with pedicles and a few of the patients with multiple phalangeal injury.

DISCUSSION

There were some misgivings at first about modifying or eliminating the well-established and accepted features, enumerated previously, in performing hand surgery. However, the results in the accumulating cases soon indicated that the simplified scheme of treatment was practicable and could be followed safely and effectively. Treatment of the patients on an ambulatory basis, in an emergency operating room and under nerve-block anesthesia allowed the repairs to be carried out often within an hour or so of the time of injury. The delay, early in this series, occasioned by the process of admission, the performance of the laboratory work and the wait for a major operating room and an anesthetist thus were eliminated. The avoidance of general anesthesia not only reduced postoperative morbidity but also obviated postanesthetic complications. The omission of antibiotics in patients with relatively small wounds in areas with excellent blood supply did not seem to be an undue risk to take. The occurrence of only three infections in this whole series amply justifies this course.

There is no doubt that the scheme of management effected substantial savings in hospitalization, anesthesia, drug and other costs, not only to the carriers but also to the patients not covered by insurance.

The effectiveness of the technic of repair evolved is attested to by the salvage of 417 distal phalanges out of 462 injured. Admittedly, many of the patients had shortening of the reconstructed phalanges, loss of some of the pad, loss of a nail and other minor defects, but all had a functional, useful distal phalanx with good flexion at the distal joint and an effective contact surface with adequate sensation. The functional and the anatomic results achieved with the use of the remaining local tissue for repair or reconstruction and a split graft to close remaining defects made it unnecessary to consider the general use of cross-finger, palmar or distal pedicle flaps. The relatively prolonged morbidity, the occasional stiff finger, especially in those over forty, and the often troublesome secondary defects resulting from their use also were eliminated in this way in this series.

Many of the phalanges reconstructed in this series might have been considered for amputation by others. This might have resulted in return of the patients to work a few days earlier. However, the average time lost from work for all the patients in this series was only 18 working days, a very

reasonable and acceptable figure. The return to work of 96.7 per cent of all the cases treated, within 8 weeks of their injury, and with functional distal phalanges, is confirmatory evidence of the satisfactory results achieved with the method presented.

SUMMARY

A series of 369 patients with compound injuries of 462 distal phalanges was presented. The surgical methods of repair for the various types of injury, utilizing remaining local tissue and split grafts, were detailed. The adoption of a scheme of ambulatory care with avoidance of hospitalization, general anesthesia, tourniquet and antibiotics simplified postoperative care and effected substantial savings in hospital costs. It was demonstrated that judicious modification of the accepted rigid conditions for reparative hand surgery could be made without compromising the results.

The effectiveness of the plan of care and the technics of repair is indicated by the salvage of all phalanges not damaged irreparably by the original injury. Further indications of the effectiveness of the method presented were the relatively few office visits required, the average loss from work of only 18 working days, and return to work of 96.7 per cent of the patients treated within 8 weeks.

Salvation de Ledite Phalanges Distal

Summario in Interlingua

Plano de Cura e Analyse de Tres Centos ■ Sexanta-Nove Casos

Es presentate un serie 369 patientes con lesiones complicate de 460 phalanges distal. Es describite in detalio le methodos chirurgic pro le reparo del varie typos de lesion, con le utilisation del remanente histo local e graffos findite. Le adoption de un plano de tractamento ■ base ambulatori sin hospitalisation, sin anesthesia general, sin tourniquet, ■ sin antibioticos simplificava le tutela postoperatori e resultava in un reduction considerabile del costos hospitalari. Esseva demonstrate que un modification judiciose del acceptate rigide conditiones pro chirurgia reparatori del mano es possibile sin risco con respecto al resultatos final.

Le efficacia del plano es reflectite per le facto que omne le phalanges esseva preservate in tanto que illos non esseva ledite ■ grados irreparabile in le accidente original. Indicationes additional del efficacia del methodo hic presentate es a vider in le relativemente basse numero de visitas requirite ab le patientes, in le facto que le perdita medie de tempore de labor esseva solmente 18 dies, e le facto que 96,7% del patientes retornava a lor occupationes intra octo septimanas post le operation.

11

Acute Trauma to the Hand

J. EDWARD FLYNN, M.D.*

Improved results with acute trauma to the hand are attributable to better knowledge, improved first aid and definitive treatment, good nutrition and, probably, antibiotics. Bacteriology of acute trauma has changed radically in the recent past. The bacteria are varied and often are more virulent. Bacteria are resistant to antibiotics. When sensitivity to antibiotics exists, it is often temporary and changeable. Therefore, we must exclude prophylactic antibiotics from our armamentarium in the treatment of acute trauma to the hand. To maintain our present high standard, it is necessary to bear well in mind the multiple details in first aid and definitive treatment. Ideal first aid ensures arrest of bleeding and protects the open wound from further contamination. Usually, it is sufficient to apply a sterile dressing, held in place by a snug bandage, and in severe cases to reinforce by a splint. Time, which permits bacteria to multiply and invade, is an important factor in selecting the primary procedure. Wounds are so variable in the extent of tissue damage, presence of foreign bodies, number and virulence of bacteria and resistance of host that the time limit is a matter of degree.

In extensive crushed or avulsed wounds, primary repair of tendons is dangerous. In cleanly incised wounds with minimal tissue damage or contamination, tendons may be repaired safely. We must exclude any thought that prophylactic antibiotics will increase the time within which tendon reconstruction can be performed safely. We must return to our preantibiotic principles. With a careful selection of cases and in questionable cases when a smear from the wound does not show cocci or an excess of leukocytes, primary repair of tendons within sheaths may be performed up to 6 hours; tendons outside sheaths, within 8 hours from the time of injury. Wounds may be closed within 8 hours.

HISTORY

An exact history of the injury is of value in preventing infection and in helping to determine the state of cleanliness of the wound, and it aids in the decision as to a primary or a delayed procedure. Five facts must be determined: The agent causing the injury, the place, the circumstances, the exact time, and the first aid rendered. It is probable that the wound is not infected and that a primary reconstruction may be performed when the injury has been caused indoors on clean hands by a sharp instrument, such as broken glass, a clean knife or a broken porcelain faucet, when the lapse of time is short and a sterile dressing is applied in a well-equipped first-aid clinic.

There is more probability of a contaminated or an infected wound, and more indications for a delayed reconstruction, when a crushing injury sustained out of doors on dirty hands causes devitalization of tissue, when many hours have elapsed and more contamination probably has been supplied when unmasked, voluble, untrained person-

* Boston, Mass

nel attempt to stop bleeding immediately after an automobile accident.

DIAGNOSIS

Adherence to many details is important in the preoperative as well as the operative phase. The history obtained on the Accident Floor is of value in determining the type and the location of the injury, and the state of cleanliness. A mask is placed over the nose and the mouth of the examiner, the first-aid dressing is removed, and the wound is inspected. At this examination, one notes only the exact location, the superficial extent, the type of wound and the apparent extent of gross contamination and devitalization. The depths of the wound are not investigated at this time. A sterile dressing is applied. Physical examination is performed for nerve, tendon and bone injury. Examination may cover the three nerves of the hand for sensory and motor loss. Areas of anesthesia to light and coarse touch are plotted. The sensory distribution of the three nerves is well understood. Motor function in the action of the intrinsics is investigated. With median nerve palsy, there is inability to abduct and oppose the thumb. With ulnar nerve palsy, there is inability to abduct and adduct the fingers, and inability to extend the two distal phalanges of the ring and the little fingers. Radial nerve palsy involves the extrinsic extensors with resultant wrist, finger and thumb drop.

An examination for tendon injury is performed. With transection of the flexor pollicis longus and the flexor digitorum profundus tendons, there is inability to flex the distal phalanx of the thumb and the other digits, respectively. It may be difficult to diagnose a transection of the sublimis tendon alone, because an intact profundus may flex a digit completely. The function of the sublimis tendon is to flex the middle phalanx and to give the final strength of pinch or grasp in a normal finger. With transection of an extrinsic extensor tendon, there is inability completely to extend the joint distal to the laceration. Bone injury may be determined clinically by a deviation from normal contour, length and alignment or by crepitus. Roentgenograms of the hand should be taken in three views: anteroposterior, lateral and oblique. Therefore, a diagnosis is made before the patient is sent to the operating room and before the depths of the wound are investigated.

OPERATIVE TECHNIC

A brachial plexus block, with Xylocaine, is used for adults with severe injuries that require 3 or more hours of operating. A nerve block with Xylocaine may be used for simple cases when less than 2 hours are required for operating and it is not necessary to use a tourniquet for hemostasis. The ulnar nerve usually is blocked at the elbow and occasionally at the wrist. The median and the radial nerves generally are blocked above the wrist. With injection of the ulnar nerve, the forearm is supinated, the nerve is palpated in the region of the internal condyle, and 2 cc. of 2 per cent Xylocaine is injected in the nerve and 5 cc. about it. The median and the radial nerves may be injected as was the ulnar nerve. The median nerve is found, as a rule, just lateral to the palmaris longus, but it may be found under the palmaris longus or as far lateral as under the flexor carpi radialis tendon. The radial nerve is injected in the superficial fascia at the lower edge of the radius. The Xylocaine is extended to the wrist to various branches of the radial nerve. The digital nerve is blocked at the base of the digit with 1 cc. of 2 per cent Xylocaine. Ephedrine never should be injected into a digit, because of the high incidence of gangrene. Ether anesthesia is used for children. Operations upon extremities are performed suitably with very light ether anesthesia.

Multiple details must be understood. All surfaces of the upper extremity are shaved from elbow to fingertips. The same area is scrubbed for 10 to 20 minutes, pHisoderm and cotton gauze being used. Brushes never

are used in the cleansing. The upper extremity then is clean mechanically. The problem now is a dry wound lined by traumatized and devitalized tissue and contaminated with bacteria that must be converted into a clean surgical wound. Irrigation is best performed by an irrigating nozzle placed deeply in the wound. Gross débridement of foreign bodies and loose and devitalized tissues may be performed during the irrigation. The irrigation is best performed on a sterile modified Bryant irrigating pan, so that irrigation may be performed under sterile conditions. From 2 to 20 liters of normal saline is used, depending upon the location, the type, the size, the depths and the contamination of the wound. A pneumatic tourniquet is used to provide hemostasis during the débridement. The area about the wound again is prepared with pHisoderm, and the part is draped for débridement. Débridement usually consists of an excision of the entire surface of the wound to a depth of 1 or 2 mm. or more, if necessary, to remove all devitalized and contaminated tissue. Irrigation will cause the surface tissues to float, so that devitalized tissue can be identified easily and excised. Early irrigation and débridement are the best prophylaxis for infection and are more important than prophylaxis by antibiotics. Proper operative technic requires a knowledge of many more details. Some of these details are: The proper selection of a primary or a delayed procedure; the closing of wounds as early as possible; atraumatic technic; hemostasis; small operating instruments; proper assistance; correct ligatures and sutures; wound suturing without tension; local rest by purposeful splinting; general rest in bed; and elevation of the injured extremity to prevent edema.

After cleansing and irrigation a decision must be made to perform a primary or a delayed operative procedure. This decision is made mainly upon the type of wound that presents itself after irrigation.

TABLE 1. CLASSIFICATION OF OPEN WOUNDS OF THE HAND

Incised Wounds
Clean (involving sheath or no sheath involved)
Dirty (involving sheath or no sheath involved)
Crushed Wounds
Clean (involving sheath or no sheath involved)
Dirty (involving sheath or no sheath involved)
Avulsed Wounds
Clean (involving sheath or no sheath involved)
Dirty (involving sheath or no sheath involved)
Specific Types
Involving fingertip
No bone exposed
Bone exposed
Finger
Flexor or extensor surface involved
Glove avulsion of fingers or hand
Volar and dorsal aspects of hand
Late Wounds
Clinically (redness, edema, smear shows cocci or increased leukocytes)
In time (incised, crushed or avulsed)
Septic Wounds

TYPES OF WOUNDS AND METHOD OF REPAIR

In Table 1 open wounds of the hand are classified according to the types encountered over a 12-year period at the Boston City Hospital. With open wounds of the hand we perform a primary repair of incised nerves in incised, crushed and avulsed wounds that have been converted from potentially infected wounds into clean surgical wounds. Crushed and avulsed nerves are best treated by early delayed repair 3 to 6 weeks after injury. Digital nerves may be sutured distally as far as the distal volar digital crease. The degree of recovery after nerve suturing is in direct proportion to the accuracy and the perfection of the juncture. With sharp scissors, each nerve is cut off until a perfect pattern of funiculi is seen, with axone bundles projecting from each end. Atraumatic eye suture with curved weld on needle, a very fine black silk Size 7-0, is used First, two guide sutures are placed in the nerve sheath only. Between the guide sutures, the sheath edges are approximated with inter-

rupted stitches. After suturing the anterior side, a guide suture is passed under the nerve, and the nerve is turned around for suturing the posterior aspect.

The radial nerve usually is transected in the mid-humeral region. Proper dynamic splinting must be used to correct wrist drop, finger drop and thumb drop, and to prevent stiffening of joints. Motor regeneration of the radial nerve after repair in the arm is usually good, but 10 to 12 months may be required for complete recovery.

The median and the ulnar nerves are transected most frequently in the wrist. With good apposition, sensory regeneration occurs in close to 100 per cent. In our experience, motor regeneration after repair of the median nerve occurs in an estimated 15 per cent, and with ulnar nerves in an estimated 5 per cent.

Purposeful splinting, following transection of the median nerve in the wrist, maintains the thumb in a position of abduction by adhesive strapping or a glove. After transection of the ulnar nerve in the wrist, the intrinsics are best rested by a movable plaster splint on the hand that maintains the metacarpophalangeal joints in 30° of flexion.

In open wounds of the hands, fractures are treated before soft-tissue injuries. Fractures are reduced by manipulation in all types of wounds except grossly septic ones. In septic wounds, fractures are reduced by gradual traction. Internal fixation with fine Kirschner stainless-steel wires may be used when the wound has been converted into a surgically clean one and proper wound coverage is available.

Arterial injuries of the upper extremity are seen in civilian practice but much more frequently in military surgery. The pathologic changes are many. The artery may be compressed by a fracture or a dislocation with or without spasm. Reduction of the fracture or dislocation usually corrects the vascular compression. A contusion of the artery may simulate transection and usually is diagnosed at operation. The clot is removed. The damaged wall of the artery is

FIG. 1. (*Top*) Glass wound of forearm causes dissecting aneurysm of radial artery. Hematoma between flexor sublimis and profundus muscles causes flexion deformity of fingers. (*Center*) Arteriogram shows defect in radial artery. (*Bottom*) Section of radial artery with dissecting aneurysm.

excised, and an autogenous venous graft is used. The critical arteries of the upper extremity are the axillary and the brachial. Previous to the Korean War, ligation of a lacerated artery generally was the treatment of choice because restorative surgery had

FIG. 2. Lacerated wound of wrist 8 hours after injury with primary repair of 12 flexor tendons, median and ulnar nerves.

not been adapted satisfactorily to war wounds and front-line military situations. In the Korean War surgery was performed on lacerated arteries at forward echelons. Injuries to major arteries were repaired, without regard for time lag, if the extremity appeared to be viable, with an amputation rate of 8.8 per cent compared with 53 per cent in World War II. The injury to the artery may be a partial or a complete severance. A partial severance of a large artery is associated with a large tense hematoma in a closed space or exsanguination in a wound. Partial division of an artery prohibits retraction of the ends into soft tissues, where bleeding could be arrested. Following division of a radial or an ulnar artery, a large hematoma between the flexor sublimis and profundus muscle causes flexion deformities of the digits (Fig. 1). A partial severance of a large artery is treated by suturing or grafting. A complete division of a large artery may allow the vessel to retract into muscle masses, where spasm and clotting often occur early. A complete division of a large artery is treated by suturing or autogenous grafting. Radial and ulnar arteries incised in the wrist should be sutured

Our problem now is resolved into two features. When shall we perform a primary reconstruction of the tendon and the wound? When shall we perform a delayed reconstruction of the tendon and the wound? Prophylactic antibiotics should not be considered in these problems.

Incised Wounds

With clean incised wounds that have been properly débrided, a primary closure of the wound may be performed up to 8 hours from the time of injury when there is no sign of inflammation or, in questionable cases, a smear of the wound shows no increase in leukocytes and no cocci. With lacerated tendons outside sheaths, a primary repair of tendons may be performed up to 8 hours after injury (Fig. 2). However, with in-

TABLE 2. TREATMENT OF OPEN INCISED WOUNDS

	WOUND TREATMENT	TENDON TREATMENT
Incised Wounds (Clean)	Primary suture if done within 8 hours or if there is no inflammation	
Outside sheath		Primary suture if done within [illegible] hours
Within sheath		Primary suture if done within 6 hours
Incised Wounds (Dirty)		
Débridement complete	Primary suture if done within 6 hours or if there is no inflammation	Primary suture if done within 4 hours
Débridement incomplete	Delayed closure; vital structures covered	No primary repair

juries to tendons within sheaths, we perform a primary repair of tendons up to 6 hours after injury.

With dirty incised wounds in which all contaminated and devitalized tissue has been excised, we believe that the wound may be closed primarily within 6 hours and the incised tendon repaired within 4 hours of the injury.

With incised wounds where complete débridement cannot be performed, no attempt is made at primary tenorrhaphy. Delayed closure of the wound is performed after vital structures are covered, if possible (Table 2).

When the flexor sublimis tendon is cut in a finger, it may not necessarily be sutured. When both sublimis and profundus tendons are cut between the distal crease in the palm and the middle volar crease in the finger, only the profundus should be repaired, and the sublimis should be removed. The profundus tendon sutured in the middle phalanx of the finger may yield a good result, as it needs to pull only one joint instead of two, as in the proximal segment. The profundus tendon sutured at its insertion usually gives a good result. Flexor profundus tendons are necessary for good results, but flexor sublimis tendons are not so important. Transection of flexor tendons in the proximal phalanx of a digit and distal 1 inch in the palm is the commonest injury, and is followed by the poorest results.

Repair of flexor tendons in the palm, proximal to entering the proximal annular sheaths, usually yields good results when both sublimis and profundus tendons are repaired and separated from each other by the lumbrical muscles.

Primary repair of multiple transected flexor or extensor tendons in the wrist or the forearm often yields an excellent result, which is far better than secondary tendon reconstruction.

For repair of transected tendons within a sheath, we have used No. 34 stainless steel with Bunnell wire pull-out technic and 3-0 silk that withstands a 5-pound pull at the knot. Our results have been about the same with each technic. Fine silk or cotton usually is used for tendon suturing in the palm, the dorsum of the hand, the wrist and the forearm, where surrounding tissues are loose enough to glide. Fine Fagersta stainless-steel wire may be used as a permanent suture.

For an avulsion of the extensor tendon at the distal joint, our best results have been with Bunnell pull-out wire technic, using No.35 stainless-steel wire.

TABLE 3. TREATMENT OF OPEN AVULSED WOUNDS

	WOUND TREATMENT	TENDON TREATMENT
Avulsed Wounds (Clean)	Primary suture if done within 6 hours or if there is no inflammation	
Outside sheath		Suture incised tendons within 6 hours; do not repair avulsed tendons.
Within sheath		Do not repair avulsed or incised tendons.
Avulsed Wounds (Dirty)		
Débridement complete	Primary closure if done within 6 hours or if the wound shows no inflammation	Suture lacerated tendons within 4 hours outside sheath; do not repair avulsed tendons.
Débridement incomplete	Delayed closure; vital structures covered	No primary repair

Avulsed Wounds

With clean avulsed wounds, a primary closure of the wound may be performed up to 6 hours from the time of injury with satisfactory débridement (Table 3). With clean avulsed wounds, avulsed tendons never are repaired primarily. With some avulsed wounds, a cleanly lacerated tendon outside a sheath may be repaired up to 6 hours from the time of injury, but lacerated tendons within a sheath are not repaired primarily.

With dirty avulsed wounds that are débrided clean, a primary closure of the wound may be performed up to 6 hours, and sharply lacerated tendons outside of sheaths in some of these wounds may be repaired up to 4 hours from time of injury.

With dirty avulsed wounds in which débridement is incomplete, no attempt is made at primary tendon repair, and delayed closure of the wound is performed.

Avulsed wounds, involving fingertips with no bone exposed, are treated with primary intermediate-thickness grafts taken from the thigh or the abdomen. With a clean avulsed wound of a fingertip and bone involved, the digital nerves are pulled distally, stretched and transected as far proximally as possible. The defect is covered by a pedicle graft cut from the thenar area of the same hand, when the index, the middle and the ring fingers are involved; from the hypothenar eminence when the littlet finger is involved; and from the dorsum of the proximal phalanx of the index or the middle fingers when the thumb is involved. The donor site of the graft then is covered with a full-thickness graft. Immobilization in a plaster cast is maintained for 2 weeks, then the graft is detached.

An avulsed wound over the volar aspect of a finger may be covered with a full-thickness graft by sliding a graft from one or both sides of a finger, or by a *pedicle* graft from the dorsum of an adjoining finger. An avulsed wound over the dorsum of a finger may be covered by an *intermediate-thickness graft* or a *full-thickness graft*, or by a primary pedicle graft from the abdomen.

Occasionally, a glove avulsion of the skin of a finger or a hand occurs, and the avulsed skin is carried to the hospital with the patient. We recognize the fact that in some of these cases the avulsed skin has been cleansed, reapplied within 2 hours of injury, and healed. However, in general, the chances of infection are too great. There is an ample source of skin for grafting in any patient, and it is safer to apply freshly cut grafts for glove avulsions.

A tubular graft with subcutaneous fat may be prepared and later replace an intermediate-thickness graft. The recipient site may be avascular and will not take a free skin graft. Then a primary pedicle or pocket graft from the abdomen may be used. A primary pedicle graft should only be used when necessary. In a primary pedicle graft, the susceptible graft may become infected, and thrombosis frequently occurs. A free graft usually will not grow on a recipient site with bone devoid of periosteum, tendons devoid of sheaths, exposed nerves or an avascular bed.

Extensive avulsed wounds over the volar *or the dorsal surface* of the hand are treated preferably by a temporary intermediate-thickness graft with later application of a tube graft. In some cases it is necessary to apply a primary pedicle graft.

The most serious extensive avulsed wounds over the volar and the dorsal aspects of the hand are treated by temporary intermediate-thickness grafts when possible (Fig. 3). In some cases it is feasible to apply an intermediate-thickness graft over the dorsum and a primary abdominal pedicle graft over the volar aspect. Rarely, a primary pedicle graft for the volar and the dorsal surfaces is indicated, and this problem may be technically difficult.

After a long operation the wound should be cultured and sensitivity tests performed if positive.

FIG. 3 (*Top*) Glove avulsion of hand with flap retracted 6 hours after injury. (*Center*) Avulsed palmar flap is not viable Flap is excised. Wound is covered with intermediate-thickness graft. (*Bottom*) Avulsed wound of dorsum is covered with intermediate-thickness graft.

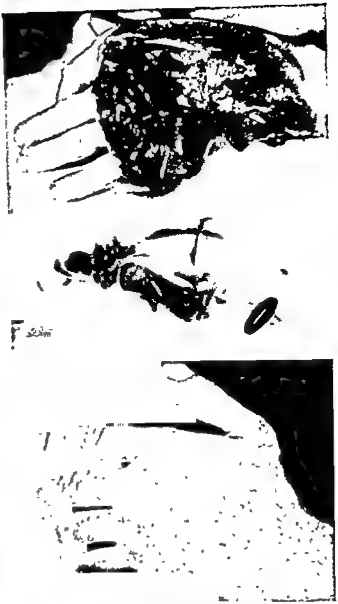


FIG. 4. (*Top*) Crushed wound 4 hours after injury; no attempt at primary repair of tendons and nerves. (*Center*) Fractures are reduced by manipulation. (*Bottom*) Wound healed primarily after adequate débridement and irrigation.

CRUSHED WOUNDS

With clean crushed open wounds adequately débrided, a primary closure of the wound is performed up to 6 hours from the time of injury (Table 4). With clean crushed open wounds, crushed tendons never are repaired primarily. With some clean crushed wounds, a cleanly incised tendon outside a sheath may be repaired primarily up to 4 hours from the time of injury, but incised tendons within a sheath are not repaired primarily (Fig. 4).

With dirty crushed wounds in which débridement is complete, primary closure of the wound may be performed up to 6 hours from the time of injury, and cleanly incised tendons in some of these crushed wounds may be reconstructed primarily up to 4

TABLE 4. TREATMENT OF OPEN CRUSHED WOUNDS

	WOUND TREATMENT	TENDON TREATMENT
Crushed Wounds (Clean)	Primary suture if done within 6 hours or if there is no inflammation	
Outside sheath		Suture incised tendons if done within 4 hours; do not repair crushed tendons.
Within sheath		Do not repair crushed or incised tendons.
Crushed Wounds (Dirty)		
Débridement complete	Primary closure if done within 6 hours or if wound shows no inflammation	Suture incised tendons if done within 4 hours outside sheath; do not repair crushed tendons
Débridement incomplete	Delayed closure; vital structures covered	No primary repair

hours from the time of injury. Crushed tendons are not repaired primarily unless the crushed area is very slight.

With dirty crushed open wounds in which complete débridement is not possible, no primary reconstruction of tendons is attempted, and a delayed closure of the wound is performed.

LATE AND SEPTIC WOUNDS

After 8 and 24 hours, depending upon the type of wound or if a smear of the wound showed cocci or increased leukocytes, the wound is called late. Bacteria have multiplied and penetrated the wound. The opportunity for complete débridement, repair of deep structures and closure of the wound is over, as these would result in infection. Late wounds are treated by removal of foreign bodies and grossly devitalized tissues, delayed closure and delayed reconstruction.

Septic wounds are treated by incision and drainage, excision of necrotic tissue, immobilization, local heat, general rest, fluids and laxatives. A culture is taken, and sensitivity tests are performed. The proper antibiotic is given. However, cultures and sensitivity tests should be repeated at weekly intervals at least, because in our experience sensitivity tests, especially with hemolytic *Staphylococcus aureus*, frequently change at weekly intervals.

PREVENTION OF TETANUS

Tetanus is not probable in a clean simple wound, although it may follow an abrasion. The presence of devitalized tissue, necrosis and foreign bodies favors tetanus. Antitetanus serum is given for all extensive open wounds and for other wounds favorable to tetanus. A skin test is performed, and, if the patient is nonsensitive, 1,500 units are given hypodermically. The immunity is short. The dose is repeated in 10 days or at subsequent operation. Active immunization from toxoid lasts several years. The serum is omitted if the patient had adequate immunization by a course of toxoid within an 8-year period, and a stimulating dose of 0.5 cc. of toxoid given. When adequate immunization is doubtful, the serum is given, and a course of toxoid is begun.

POSTOPERATIVE TREATMENT

Petrolatum gauze, with a very fine film of petrolatum, is placed over the wound. A sterile gauze dressing is applied with moderate compression to check the ooze of lymph and the formation of hematoma. Anterior and posterior splints maintain com-

pression and proper position and provide local rest. The limb should be elevated by suspending the wrist from an irrigating stand to prevent congestion, oozing, thrombosis, cyanosis and compression of tissues from swelling.

General rest in bed is important to enhance the prevention of infection and the healing of injured tissues. Motions should not be instituted until the wound is healed. Motions in a recently injured hand increase exudate and favor infection. Flexor tendon injuries, nerve injuries and fractures of digits usually are immobilized for 3 weeks. Extensor tendon injuries are immobilized for 5 weeks. When wounds are healed, active motions, active resistive motions as with a rubber ball or a sponge rubber, and whirlpool baths aid in the restoration of function and local nutrition. When contractures occur, all scar must be excised. Transplants of paratenon and skin, proper skin closure and dynamic splinting help to correct the deformity.

SUMMARY

The maximum results in the treatment of open wounds of the hand are obtained when one observes the many details in first aid, history, physical examination, preoperative diagnosis, anesthesia, shaving, cleansing, irrigation, débridement, the selection of a primary or a delayed procedure, the early closure of wounds without tension, atraumatic technic, tourniquet, hemostasis, proper ligatures and sutures, purposeful splinting, local rest, general rest, elevation of limb, active and active resistive motions, and dynamic splinting.

For 10 years antibiotics seemed to be of value prophylactically with acute trauma to the hand. However, in the recent past, bacteria have increased in virulence and in resistance to antibiotics so that one would not know which antibiotic to use prophylactically. After long operations, a culture of the wound is taken, and, if possible, sensitivity tests are performed.

BIBLIOGRAPHY

Auchincloss, Hugh: Surgery of the hand, *in* Nelson Loose-Leaf Living Surgery, vol. 3, chap. 5, New York, Nelson, 1932.

Bancroft, F. W.: Treatment of traumas of skin and subcutaneous tissues, Surg., Gynec. & Obst. 72:318-327, 1941.

Bentley, F. H.: The treatment of flesh wounds by early secondary suture and penicillin, Brit. J. Surg. 32:132-139, 1944.

Bisgard, J. D., and Baker, C. P.: Treatment of fresh traumatic and contaminated surgical wounds, Surg., Gynec. & Obst. 74:20-26, 1942.

Brown, J. J. M.: Early closure of soft-tissue wounds with chemo-therapeutic agents, Brit. J. Surg. 32:140-143, 1944.

Bunnell, Sterling: Suggestions to improve the early treatment of hand injuries, Bull. U. S. Army M. Dept. 88:78-82, 1945.

———: Surgery of the Hand, ed. 2, Philadelphia, Lippincott, 1956.

Culter, C. W., Jr.: The Hand: Its Disabilities and Diseases, Philadelphia, Saunders, 1942.

DeBakey and Simeone: Battle injuries of arteries in World War II, Ann. Surg. 123:534-579, 1946.

Finland, Maxwell: Personal communication.

Flynn, J. E.: Compound wounds of the hand, Ann. Surg. 135:500-507, 1952.

———: Problems with trauma to the hand, J. Bone & Joint Surg. 35A:132-140, 1953.

Hart, D.: Surgery of the hand *in* Lewis' Practice of Surgery, vol. 5, chap. 10, Hagerstown, Md., Prior, 1940.

Iselin, Marc: Surgery of the Hand (translated by T. M. J. d'Offay and T. B. Monat), Philadelphia, Blakiston, 1940.

Jahnke, E. J., Jr., and Seeley, S. T.: Acute vascular injuries in Korean War, Ann. Surg. 138:158-177, 1953.

Jones, R. A.: Method for closing traumatic defect of finger tip, Am J. Surg. 55:326-338, 1942.

Koch, S. L.: Injuries of the hand, J.A.M.A. 107:1044-1049, 1936.

———: The treatment of hand injuries, New England J. Med. 225:105-109, 1941.

Koch, S. L., and Mason, M. L.: Division of the nerves and tendons of the hand; with discussion of the surgical treatment and its results, Surg., Gynec. & Obst. 56:1-33, 1933.

Lowry, K. F., and Curtis, G. M.: Delayed suture in the management of wounds; analysis of 721 traumatic wounds illustrating the influence of time interval in wound repair, Am. J. Surg. 80:280-287, 1950.

Marble, H.: Management of hand injuries, J. Indust. Hyg. & Toxicol. 26:189-192, 1944.

Mason, M. L.: Primary and secondary tendon suture, Surg., Gynec. & Obst. 70:393-402, 1940.

Meleney, F. L.: The difficulty of evaluating drug treatment in surgical infections, J.A.M.A. 124:1021-1026, 1944.

———: Recent experiences with penicillin in the treatment of surgical infections, Bull. New York Acad. Med. 20:517-537, 1944.

Meleney, F. L., and Whipple, A. O.: A statistical analysis of a study of the prevention of infection in soft part wounds, compound fractures, and burns with special reference to the sulfonamides, Surg., Gynec. & Obst. 80:263-296, 1945.

Mueller, R. F.: Management of compound injuries of the hand, Minnesota Med. 27:110-114, 1944.

Slocum, D. B., and Pratt, D. R.: The principles of amputations of the fingers and hand, J. Bone & Joint Surg. 26:535-546, 1944.

Stevenson, T. W., Jr.: Principles of treatment of avulsion of skin, S. Clin. North America 21: 555-564, 1941.

Sullivan, J. E.: Immobilization in the treatment of wounds of the extremities, S. Clin. North America 21:571-576, 1941.

Wilson, H.: Secondary suture of war wounds: a clinical study of 305 secondary closures, Ann. Surg. 121:152-156, 1941.

Winfield, J. M.: Anatomic diagnosis of injuries of the hand, J.A.M.A. 116:1367-1370, 1941.

Trauma Acute del Mano

Summario in Interlingua

Resultatos optimal in le tractamento de vulneres aperte del mano es obtenibile si on observa omne le detalios que entra in le prime succurso e in le tractamento definitive. Usualmente le application de un sterile bandage compressive—sin examine del vulnere—suffice como prime succurso.

Le observation de detalios in le tractamento definitive comencia in le sala de reception pro victimas de accidentes. Illac es obtenite un historia del caso, incluse le agente de causation, le placia, circumstantias, e tempore precise del accidente, e le forma de prime succurso que esseva applicate. Le prime bandage es removite, e le vulnere es inspicite simplemente. Un nove bandage sterile es applicate, e le lesiones de osso, tendine, e nervo es determinate per un examine physic. Sub anesthesia general le vulnere e le area circumjacente le vulnere es rendite chirurgicamente limpide.

Vulneres aperte del mano pote esser classificate secundo lor origine como vulneres de incision, de contusion, e de avulsion. Iste tres classes ha sub-gruppos de vulneres limpide e vulneres contaminate. Un quarte e un quinte classe consiste de vulneres tardive e de vulneres septic. Reparo primari de nervos incisionate es effectuate in omne casos con le exception del vulneres septic. Nervos contundite e avulsionate es reconstruite circa tres septimanas post le accidente. Fracturas es reducite per manipulation in omne vulneres con le exception del vulneres septic. *In vulneres septic, fracturas* es reducite per traction gradual. Tendines contundite e avulsionate non es tractate per reparo primari In le caso de tendines a laceration nette, il es possibile effectuar un reparo primari intra sex a octo horas post le accidente.

In le recente passato, le bacteriologia de trauma acute del mano se ha alterate. Le bacterios varia. Illos es plus virulente e ha devenite plus resistente a antibioticos. Il es difficile saper qual antibiotico on debe usar pro objectivos prophylactic. Post prolongate operationes, culturas es facite ab le vulneres, e si illos es positive, tests de sensibilitate es effectuate.

12

Acute Open Flexor Tendon Injuries of the Hand

HARRY MILLER, M.D., F.A.C.S.*

INTRODUCTION

The severance of tendons of the hand is a common hazard that results frequently in marked disability. It presents the doctor with real, and often grave, problems because of the expense entailed to patient, industry and insurance companies. Despite the importance of care in handling these cases, too frequently they are considered lightly, and the most inexperienced house officer is detailed to their care. When such a situation exists, bad results are to be expected. Admittedly, the successful repair of a flexor tendon is surrounded by difficulties, but, unless the problem is considered lightly, there is no need for the pessimistic view of some that successful repair of flexor tendons cut in their digital course is almost impossible.

The great number of failures of treatment has served to stimulate investigation in this field, leading to research in the physiology and the healing processes of tendons, to the establishment of time limits within which tendon repair can be accomplished successfully, to perfecting old technics for tendon repair and developing new methods of repair, and to re-evaluating our concepts regarding primary tendon suture, delayed suture, and primary and delayed tendon grafting.

Three important considerations are necessary in the care of severed tendons: (1) Determination of nature, extent and location of injury; (2) accurate and painstaking care in repair; and (3) perseverance in restoring function.

* Allentown, Pa.

DETERMINATION OF NATURE AND EXTENT OF INJURY—DIAGNOSIS

The examination of the hand to determine the nature of the injury is directed primarily toward determining deviations from normal function. Accordingly, the *hand* is to be examined, *not the wound*. To probe the wound is dangerous and contributes nothing. Every tendon has a definite function to perform, and, if there is disturbance of normal movements of the hand, it should be assumed that the tendons and/or the nerves are injured. Functional loss may be due to disruption of bony architecture. If roentgenograms are indicated, these should be obtained before surgery.

The diagnosis of tendon and nerve injuries has been covered adequately in publications by Couch,[6] Winfield[37] and others. The most valuable diagnostic information is obtained by determining loss of motor power. Testing for sensory changes often is unreliable in the presence of acute injuries. However, it is not infrequent for the patient to volunteer the information that he has no feeling in one or another of his fingers. It is difficult to assess the child in fear and pain and the un-co-operative adult, such as the intoxicated, the unconscious and the psychotic. Active movements may be observed. The

position of the fingers at rest and in motion will give one a clue as to the integrity of the tendons distal to the site of laceration. With complete division of tendons there is a disappearance of the semiflexed position of the fingers at rest. Isolated sublimis tendon lacerations usually are diagnosed during débridement and wound exploration. When painstaking attempts at determining alterations in sensation have been unreliable, it is *essential that digital nerves be exposed for* direct inspection.

Frequently a tendon will be severed partially. Routine tests at the preliminary examination will reveal good function, but complete separation will occur at a later date when motion is resumed. To avoid this embarrassing situation, the tendon should be flexed against counterpressure at the original examination.

CRITERIA FOR REPAIR OF TENDONS

The decision as to whether or not a tendon is repairable is based on the following: (1) Evaluation of nature and extent of injury to the hand and the patient; (2) possibility of prevention of infection, evaluation of time factor and source of infection; (3) nature of first-aid treatment; (4) availability of proper equipment and adequate assistance; and (5) training and moral obligations of the surgeon.

Evaluation of Nature and Extent of Injury to the Hand and the Patient

Prior to embarking on a plan of treatment of the patient with an injury to the tendons of his hand, it is essential that the surgeon have a clear picture of the events surrounding the injury. *First, in the category* of historical data, it is important that he know the history of the injury, the degree and the source of contamination, the nature of the damaging force, the type of first-aid care received, and the time elapsed since occurrence of the injury. *Second, he must* evaluate critically the nature of the wound; whether it is a clean knife cut or a crushed and contused wound associated or not with underlying fractures or joint disruption, and whether or not it can be resurfaced successfully. *Wounds with severe crushing, with* loss of surface covering, compound fractures with displacement of fragments and associated with lacerated tendons, are treated by débridement, reduction of fractures and resurfacing. Secondary procedures are done *to restore function.*

In the patient with serious injuries elsewhere in the body, primary tendon surgery should not be done. When there is marked lack of co-operation resulting from maniacal drunkenness or from psychotic episodes, primary repair is not done unless close postoperative supervision is available. We have done primary repair on several such patients and found a completely disrupted wound and twisted metal splint or broken cast within a few hours.

Prevention of Infection—Time Factor

The prevention of infection is a major consideration, for on its elimination rests the success of the tendon repair. The prevention of infection is dependent on prompt *removal of contamination by early surgery.* Lacerations involving tendons, if untreated for more than 4 hours, are best treated by careful cleansing of the wound, débridement and closure of the subcutaneous tissues and skin. When primary healing has occurred, *secondary repair may be performed in 3 to* 4 weeks. On occasions, clean knife lacerations at the wrist and over the dorsum of the hand, the proximal palm and the thumb are repaired as late as [illegible] hours after occurrence. Lacerations of flexor tendons in their digital *course as well as in the distal palm* are not sutured primarily if over 4 hours old. If the wound is a cleanly incised one and less than 4 hours old, primary repair, even if within the digital sheath, will give satisfactory results in about 50 per cent of cases. With the use of antibiotics, Flynn[7] has extended the time limit for primary tendon suture to

24 hours for those cleanly incised wounds outside the sheath and to 12 hours for the sheath-enclosed tendons. The incised dirty wounds, in which complete débridement was possible, had primary tendon repair if operated upon within 8 hours. The increasing resistance of many bacteria to antibiotics would indicate that they are not as complete a safeguard as has been suggested. Antibiotics are not substitutes for thorough surgery.

Lacerations of tendons contaminated by human sources are *never sutured*. Mechanical cleansing of the wound without closure of the skin is carried out. Thorough mechanical cleansing often is sufficient to permit primary healing. Tendon surgery is delayed many months lest too early dissection reactivate the infection.

Nature of First-Aid Treatment

Faulty first aid serves to break down resistance of tissues and contraindicates primary suture of tendons. In order to maintain tissue resistance at its highest level, it is imperative that we avoid (1) the use of unsterile instruments, dressings and hands, (2) the mass ligature and crushing of vessels and surrounding tissues with heavy suture material, and (3) the use of strong antiseptics within the wound.

Availability of Proper Equipment and Adequate Assistance

It is unwise to attempt tendon repair without adequate assistance and equipment. Successful tendon repair demands the best of operating-room facilities and should not be attempted in the emergency room or in the office. The use of fine plastic instruments and fine silk suture materials is essential to good repair. Iris scissors, Senn retractors, fine Adson forceps, mosquito hemostats, fine curved and straight Carrel arterial needles should compose the armamentarium for tendon repair. We have employed fine 4-0 and 6-0 silk for tendon repair, except for strong wrist extensors and flexors, where 1-0 silk was used. The eye silk 6-0 is used for apposition sutures. In employing the Bunnell technic we have used No. 35 wire.

Training and Moral Obligations of the Surgeon

Morally, it is essential that the surgeon recognize his limitations. He must be acquainted with the detailed anatomy of the hand. He must know the technics of tendon and nerve repair, of skin replacement, and of bone and joint reconstruction. He must have knowledge of old standard technics and those newly developed, and must understand the technical limitations of each in a specific circumstance. He must know that, as Mason and Bell[21] have pointed out, "surgery of the hand is definitely not for the surgeon in a hurry." He must be versed in the various benefits and hazards of physiotherapy and know the details of dynamic and fixed splinting. He must recognize the psychological and the sociologic impact of his injury, and use every effort to rehabilitate the patient with dispatch.

PREOPERATIVE PREPARATION AND REPAIR

In the preparation of the hand we have followed the technic described repeatedly by Koch.[11] When the extent of the injury has been determined, the patient is taken to the operating room. The dressing, with the exception of that portion covering the wound, is removed. The surrounding skin is shaved primarily, the fingernails are cleaned, and the hand is washed carefully with soap for a period of 5 minutes and irrigated with saline; pHisoderm is preferred. The covering of the wound then is removed, and gentle washing with cotton sponges is continued for a full 10 minutes. Cotton sponges are changed frequently. The wound is irrigated with several quarts of warm saline. No antiseptics are applied because of their deleterious effect on healing and their masking effect on the skin. In greasy hands, ether is used to dissolve the oils. This prepa-

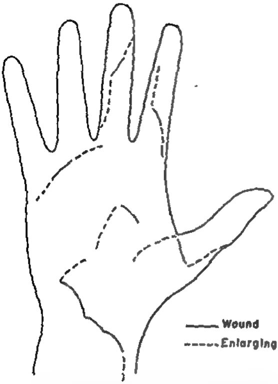


FIG. 1. Adequate access is necessary to permit repair without rough handling and retraction. Enlarging incisions are so made as to follow physiologic lines; they must *not lie in the mid-line, they must not cross* flexion creases, and, above all, cruciate enlargement must be avoided (After Mason, M. L.: Postgrad. Med. 22:163)

ration is performed under general anesthesia and in the presence of a bloodless field obtained by inflation of the pneumatic cuff to 250 mm. Hg. In patients for whom general anesthesia is contraindicated, such as accident victims who have eaten recently and other poor-risk patients—cardiac, etc.—brachial plexus block has proved to be valuable.

PREOPERATIVE ASSESSMENT OF SKIN VIABILITY

Crushing forces will result in structural damage of the skin. A correct appraisal of its viability is vital to successful resurfacing, without which successful tendon surgery is not possible. The injury to veins and arteries will result in ecchymosis and thrombosis of subcutaneous *fat that will heal by scar re*placement, thus negating a technically expert repair. As an aid in the evaluation of skin viability, Mason[19] has suggested the tourniquet test, which is as follows: The pneu*matic cuff utilized to obtain* a bloodless field is released, and the return of circula*tion during the stage of reactive hyperemia* is observed. According to Mason, "Avascular areas show up dead white against the bright pink background." Sometimes the hyperemic blush does not come all at once but appears later in some areas than in others; therefore, it is essential that observation be continued for several minutes before deciding whether or not to excise skin.

TECHNIC OF TENDON REPAIR—ADEQUATE EXPOSURE

The first objective in planning definitive surgical treatment is to gain adequate exposure, the requirements of which are as follows:

1. A Properly Placed Incision. *The* majority of wounds of the hands are trans*verse in direction and, usually, too small* for adequate visualization of the underlying tissues; these are best enlarged by making longitudinal incisions distally and proximally from either end of the original laceration *along the sides of the digits.* Enlarging incisions running perpendicular to the flexion *creases of the palm or down the mid-line of* the fingers or the wrist should be avoided whenever possible. An *incision running per*pendicularly through the center of a laceration will come together in four flaps, the tips of which are approximated with difficulty and, because of poor blood supply, tend to become necrotic, leaving exposed *the line* of tendon suture, thus further decreasing the *chances of a good result.* Mid-line incisions tend to form contracting mid-line scars, which in themselves will impair function. It is important that the incision be planned carefully so that the line of tendon suture is covered with a good subcutaneous pad *and* that there be no contractile scar. Tendon exposure in the finger is obtained by means of a mid-lateral incision, while in the palm

a transverse incision is made in the distal flexion crease. (Fig. 1)

2. **Thorough Hemostasis.** Tendon surgery requires a bloodless field, for, as Bunnell[7] has stated, "to operate upon a hand immersed in blood is like a jeweler trying to repair a watch immersed in an inkwell."

3. **Good Relaxation of the Muscles of the Hand So That It Can Be Pronated, Suppinated, Flexed and Extended Without Undue Force.** This presupposes good anesthesia, either general anesthesia or brachial plexus block.

4. **Good Retraction.** This must be obtained with a minimum of force so as to eliminate trauma and minimize edema formation and subsequent scar-tissue growth so disastrous to a successful result.

5. **Good Illumination.** This requires not only adequate overhead lighting but all possible facilities for acute visualization of the vital structures, especially the digital nerves. A common question is, "Are the digital nerves not too small to be sutured?" If this appears to be so, then it is imperative that one use a magnifying loop, as used by eye surgeons, or retire from doing hand surgery.

CHOOSING TECHNIC OF TENDON SUTURE

As has been pointed out by Mason and Allen,[20] in choosing a method of tendon repair several factors must be taken into consideration:

1. The apposed tendon ends must be free of foreign material (silk) between them.
2. There must be no impairment of blood supply to the tendon as a result of a constricting circular suture.
3. The line of tension should be perpendicular rather than parallel to the direction of the tendon fibers.

The methods described by Mason and Allen[20] best adhere to these requirements. With this technic there is less tendency for slipping of the suture and disruption of the repair, since each suture functions as a

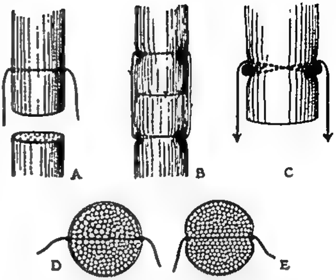


FIG. 2. Method of tendon suture in which the longitudinal pull of the suture is converted into a transverse pull across the center of the tendon. (Mason, M. L.: Surg., Gynec. & Obst. 72:392-402)

complete unit, each of which will hold the ends in approximation. (Fig. 2)

OPERATIVE DRESSING OF HAND WOUND

As soon as the dissection has been completed, the tendons and the nerves identified and sutures placed, the pneumatic cuff is deflated, and gauze pressure is maintained in the wound for several minutes. Following the subsidence of the hyperemia, all actively bleeding vessels are grasped and ligated. The arm is drained again of its blood, either by elevation for 5 minutes or by the use of an Esmarch rubber bandage, and the cuff is reinflated to 250 to 300 mm. Hg. Tendon and nerve repair is completed. The skin is closed in two layers, using 4-0 plain silk or cotton for the subcutaneous tissue closure and 4-0 dermal or nylon for the epidermal closure.

The closed wound is covered with a few thicknesses of moist, fine mesh gauze and fluffed gauze, and a compression bandage is applied. Care should be taken to prevent intertrigo caused by skin folding on itself in flexion creases. This is accomplished by

placing fine mesh gauze between the fingers and in the flexion creases.

SPLINTING

Utilizing either plaster-of-Paris casts or aluminum splints, the hand in the case of repaired flexor tendons is immobilized with maximum flexion at the metacarpophalangeal and the wrist joints. As has been emphasized by Bruner,[4] forcible flexion at these joints or at the interphalangeal joints puts excessive strain on the joint structures and is acutely uncomfortable. In the immobilization of extensor tendons, one must avoid hyperextension of the wrist and the fingers for the same reasons as given above.

RESTORATION OF FUNCTION

"Restoration of function occurs in direct ratio to the surgeon's ability to control all factors which influence wound healing"—Siler.[33] The ideal in the surgical treatment of severed tendons is restoration of physiologic function. This presupposes a knowledge of anatomy and the interrelationship of the physiologic function of the component parts of the vital anatomy of hand, wrist, forearm, arm and shoulder. Mere anatomic reposition of tissues without favorable physiologic response to our surgical efforts leaves much to be desired. Having completed the definitive surgery upon the tendons, the major effort must be directed at restoration of function.

Unless one understands specifically the physiology and the pathology of tendon healing, the results of the most meticulous surgery are apt to be disappointing. The various phases of tendon healing have been worked out in detail by Mason and the late Harvey Allen.[20] They have demonstrated the correlation between the degree of immediate postoperative motion permitted and functional loss. Based on these observations, we have followed the undernoted postoperative regimen:

1. The hand and the forearm are elevated immediately after operation by suspension of cast or on pillows or overhead frame, which is preferred, to encourage venous and lymphatic drainage.

2. Frequent checks are made of fingers for change in temperature, color and swelling, and of splint for position and constrictive irritations.

3. Initial dressing in adults is not disturbed for 10 to 14 days unless there is reason to suspect complicating hematoma or infection. At this time mild active motion is encouraged. The sutures are removed, and the splint is reapplied with the fingers and the wrist unchanged in their degree of flexion. At the end of 3 weeks, the degree of flexion at the wrist is changed to the neutral position, and the entire splint is moved distalward in order to permit active flexion, limit extension and protect the involved digits against sudden extension forces.

In children the initial dressing is maintained intact for a full 3 weeks unless reasons for earlier inspection of the wound present themselves, such as infection, skin maceration because of excessive heat, evidence of excessive bleeding, disruption of cast or displacement of the splint. The use of 5-0 chromic catgut in the skin obviates the need of early dressing to remove sutures. The cast in children should be strong and should include the lower arm and the elbow, as children will break or wiggle out of the strongest or most restraining cast.

4. Mild active motion is begun between the third and the fourth weeks. The splint is retained till the end of the fourth week. During this time it is essential that motion of the elbow and the shoulder joints be encouraged. Ankylosis in the older age groups may occur in a relatively short time and result in an elbow-shoulder disability that outweighs the hand disability.

5. Between the third and the fourth weeks the splint is adjusted so that the patient can remove it for active daily hydrotherapy, such as washing the hand in warm, soapy water

and active flexion for 5 minutes four to six times daily.

6. The splint is discarded after 4 weeks in the case of flexor tendons and 5 weeks in extensor tendons.

7. There is weekly follow-up, and careful instruction is given regarding passive joint motion exercises (Figs. 3 & 4), soaking, and the use of a rubber ball, modeling clay or Bunnell wooden sanding blocks of various shapes. Each joint of the involved fingers should be exercised individually by fixing the more proximal portion of the finger and the wrist in extension with the other hand. The performance of manual work, graded to the individual capacity, will aid greatly in more rapid return of maximal function.

PLAN OF TREATMENT OF FLEXOR TENDON LESIONS OF THE HAND

Tendons severed at different levels present separate and distinct problems in treatment. Therefore, treatment will be discussed under three headings: (1) Tendons cut in No Man's Land; (2) tendons cut distal to the sublimis insertion; and (3) tendons cut in the thumb, the proximal palm, the carpal tunnel and the wrist.

Some of the problems encountered in the treatment will be emphasized in connection with the presentation of cases.

Tendons Cut in Their Course Through the Fingers—Flexor Tendons Cut in No Man's Land

When the flexor tendons are divided between the distal flexion crease of the palm and the insertion of the sublimis tendon, several courses of action are open to the operator. These are: (1) Wound débridement and skin closure, delayed tendon repair or grafting; (2) excision of sublimis tendon and primary end-to-end suture of profundus tendon; and (3) excision of sublimis and profundus tendons and primary tendon grafting.

Case 1. W. S., age 46 years. Woodshaver injury to right hand.

Vital Injury. *Right Long Finger:* (1) Partial laceration of flexor sublimis over proximal phalanx; and (2) laceration of flexor pollicis longus at point of attachment to distal phalanx.

Right Index Finger: (1) Laceration of radial digital nerve; (2) laceration of extensor tendon through middle interphalangeal joint; (3) complete laceration of sublimis and partial laceration of profundus tendon; and (4) comminuted fractures involving articulating surfaces of the middle interphalangeal joint with loss of segments of bone.

Right Thumb: Surface abrasions and laceration of volar aspect of distal phalanx. Definitive surgery: Careful débridement. Bloodless field, general anesthesia.

Right Long Finger: Flexor profundus tendon

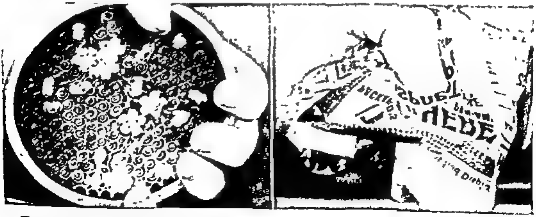


Fig. 3. (*Left*) Cocktail coaster makes excellent prop for flexion exercises of distal interphalangeal joints and profundus tendon lacerations. (*Right*) The crumpling of a double sheet of newspaper by gathering into the palm serves as a good all-purpose exercise.

FIGS. 4-6. Demonstrating woodshaver injury and resulting deformity. Fig. 4 (*Above*) (*Top*) Note (1) extended terminal phalanx of long finger, (2) complete disruption of proximal interphalangeal joint of index finger and (3) laceration of thumb. (*Bottom*) Result after 6-month follow-up. Note excellent flexion of terminal phalanx of long finger.

FIG. 5. Lines of original laceration.

advancement and reattached after technic of Bunnell with No. 35 wire. Sublimis tendon cut and permitted to retract into palm.

lacerated profundus tendon ; Sublimis tendon cut short and permitted to retract into palm.

FOLLOW-UP. Figures 4 to 6

FIG. 6. Result 1½ year ve treatment.

Comment

In reviewing this case it would seem that according to time-accepted general principles, our judgment in proceeding with definitive repair of the tendons and fixation of the interphalangeal joint in flexion with Kirschner wires was faulty, and, by and large, it should be considered so. However, the patient refused amputation of the index fingers; therefore, we proceeded with definitive surgery.

Several factors militated against the successful result of primary tendon suture: (1) The nature of injuring force that usually causes a good deal of bruising with resulting edema and fibrosis due to embedded wood sawdust; and (2) the presence of fracture and joint disruption together with nerve and tendon lacerations.

Generally speaking, primary flexor tendon suture at the site of fracture of phalanges or metacarpals will result in failure because of destruction of gliding function by bone callus and soft-tissue fibrosis. Joint involvement usually results in stiffness. Even a gliding tendon cannot move a stiff joint. Extensive dissection often is required to uncover the retracted tendon ends. If primary tendon repair is completed in the face of fractures, there is difficulty in maintaining relaxation after repair. The position of the fingers to maintain relaxation of tendons may be antagonistic to that required for maintenance of reduction of the fractured bones. However, in the case of lacerated extensor tendons, if accurate reduction can be obtained and maintained, primary suture may be done with successful functional result. In Bell, Mason and Allen's[1] series on crushing wounds involving tendon lacerations, only 2 out of 9 patients had primary flexor tendon repair, whereas 19 out of 20 had primary extensor tendon repair.

Because of the great tendency to scar formation at this level, many surgeons such as Mason,[18] Boyes,[2] Posch,[27] Littler,[15] Strandell[35] and others have adopted the policy of refraining from primary tendon repair. They prefer carefully to cleanse and débride the wound and close the skin. As soon as the wound has healed, the skin becomes soft and pliable, and passive joint function complete (Fig. 7), which usually is in 3 to 4 weeks, when secondary repair by free tendon graft is done. Graphic comparisons by Van't Hof and Heiple[36] indicate that the results of grafts within the flexor tunnel are better than those in primary repair.

Excision of Sublimis Tendon and End-to-End Suture of Profundus Tendon

Case 2. R. K., male, age 6 years. Hand thrust through windowpane.

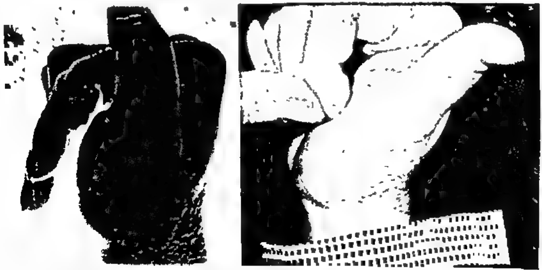


Fig. 7. (*Left*) Tendon graft will not move a stiff joint. (*Right*) Complete passive joint function, essential before grafting procedures. Skin must be soft and pliable.

VITAL INJURY. *Left Index Finger:* Laceration at web region, superficial and deep flexor tendons (Fig. 8).

Comment

In selected cases, where the 4-hour limit has not been exceeded, the contamination is minimal, and the injury is a clean cut associated with little or no contusion, without associated fractures and with the patient in good condition, we have done primary tendon suture. More cures are obtained if only the deep tendon is sutured. The crowding into the confines of the fibrosseous tunnel is the fingers of four tendon ends, increased in bulk by edema and suture material, will result in an adherent fibrotic mass that never can develop any effective gliding function.

As has been pointed out repeatedly by Koch and Mason,[13] the tendon sheath should not be sutured; the line of tendon suture should be in contact with a generous layer of subcutaneous fat. Peacock[26] has demonstrated that the blood supply to the middle third of the tendon is from the peritenon. After injury, the middle third can obtain a supplemental blood supply from adhesions; however, if these adhesions are prevented, normal healing may not occur, and aseptic necrosis will follow. Adhesions with a good vascular supply between the sutured tendon ends are best obtained by excising a section of tendon sheath, 1 cm. above and 1 cm. below the tendon suture line, thus obtaining well-vascularized subcutaneous-tissue contact. When healing has occurred, these adhesions are broken down more easily than those established between tendon sheath and tendon suture line.

On removing the sublimis tendon it is essential not to cut its insertion too long, for this stump is apt to attach itself to the flexor digitorum profundus and result in a flexion contracture of the finger. On the other hand, a hyperextension deformity of the proximal interphalangeal joint will result if the sublimis insertion is cut too short. As Graham[10] has pointed out, this deformity can be obviated by attaching the distal stump of the sublimis across the joint to the proximal phalanx in 10° flexion. The proximal stump

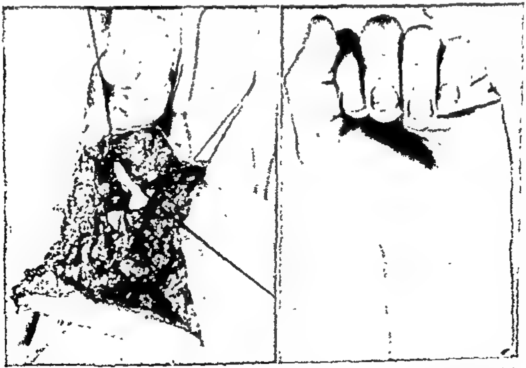


FIG 8. (*Left*) Primary suture after technic of Mason and Allen (*Right*) Two-year follow-up, primary tendon suture. Note assistance by long finger in last few degrees of index finger, flexion at terminal phalanx.

of the sublimis is removed by first acutely flexing the wrist and the fingers and then pulling it distally through the laceration as far as it will go, sectioning it and permitting it to retract into the palm.

Excision of Tendon and Primary Tendon Grafting

Case 3. W. P., age 30 years. Milk deliverer. Patient slipped on ice and cut left thumb on edge of a broken milk bottle.

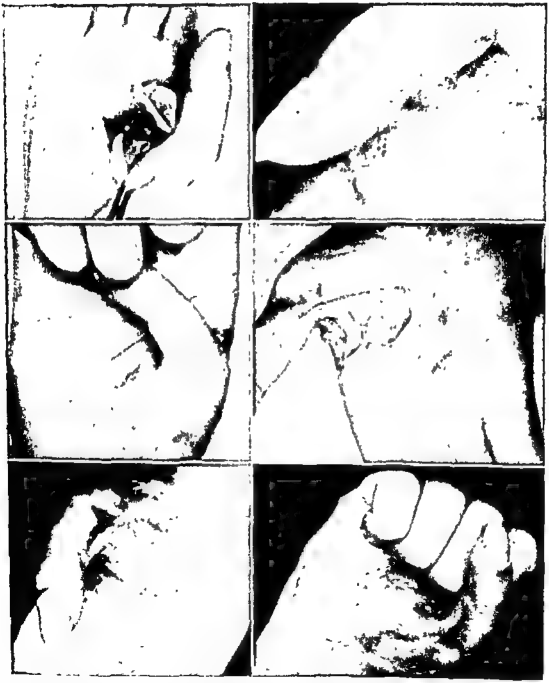


Fig. 9. (*Top, left*) Ragged laceration 2½ inches across thenar eminence with section of thenar muscles, motor branch of median nerve, flexor pollicis longus, radial and ulnar digital nerves to thumb (*Top, right, and center, left*) Flexion adduction deformity of thumb. Three months after injury sensation returned to thumb (*Center, right*) Split-thickness skin graft placed 10 months after injury limits extension (*Bottom, left*) Eighteen months after injury scar excised and rotation flap taken from proximal thenar eminence; Kirschner wire extending between first and second metacarpals maintained abduction. (*Bottom, right*) Functional result.

VITAL INJURY. *Left Thumb:* (1) Ragged laceration, 2½ inches across the thumb; (2) flexor pollicis longus cut and torn loose at base of first metacarpal; (3) laceration of thenar muscles, radial digital nerve to index finger; and (4) radial and ulnar digital nerves to thumb and motor branch of median nerve.

Definitive surgery: Bloodless field, general anesthesia. Débridement. Primary palmaris longus graft placed after excising pollicis longus tendon from wrist level to insertion. Suture of nerves with 6-0 silk. Wound closure, application of cast (Fig. 9).

Comment

It seems in retrospect that the element of crushing (Fig. 9, *top, left*) should have precluded immediate definitive tendon surgery at all, much less immediate primary grafting. The avulsing effect resulting from the irregular, jagged lacerating glass of the milk bottle served to tear the skin and pull it away from its base, causing more dermal damage than was apparent on first inspection. The marked scarring, as evidenced in Figure 9, top, right, certainly would indicate this to be so. Results of flexor tendon grafting are best when the tissues are least damaged, are soft and pliable, and there is no minimal scarring.

The functional advantage of full-thickness skin, especially on the palmar aspect of the hand and more particularly in the cleft between the thumb and the index finger, as in this case, was obtained by rotating skin flaps. Much surgery might have been avoided by immediate or delayed pedicle grafting and subsequent tendon grafting. In placing this tendon graft it might have been better to make it slightly longer, since in healing there was definite contracture and shortening with resultant 30° flexion deformity of the terminal phalanx of the thumb (Fig. 9, *bottom, left*).

Siler,[32] Boyes,[2] Flynn,[7] Graham[10] and others have reported good results with primary tendon grafting in selected cases, cleanly incised wounds with no element of avulsion or crushing. I am reluctant to consider the use of a tendon graft immediately after division of flexor tendons within the digital tunnel, for an error in judgment as to the extent of damage and thoroughness of débridement would result in either infection or aseptic necrosis. This may preclude any further reconstructive surgery and make amputation mandatory.

As has been our habit, in this case we used a long graft extending from insertion to distal forearm. Boyes[2] has used successfully a short graft with the proximal row of sutures in the thenar eminence, but he feels that wherever possible the long graft should be used. In the two cases in which he used a long graft with the proximal suture at the musculotendinous junction, the results were the best in his series, one attaining flexion of 95 per cent of normal and the other 80 per cent of normal. Strandell[35] obtained excellent results in 19 out of 21 cases treated in this manner.

Littler,[15] Rand and Wakefield,[31] Kyle and Eyrebrook,[14] Boyes,[2] Flynn,[7] and Posch[29] reported 229 cases of delayed flexor tendon grafting in No Man's Land with over-all good

Comparison of Results of Primary Tendon Suture with Tendon Grafting

	TECHNIC	CASES	GOOD	FAIR	POOR
Boyes[2]	Primary suture	89	16	33	51
	Tendon grafting	27	75		
Flynn[7]	Tendon grafting	66	55	3	21
Posch[28]	Primary suture	45	39		
	Tendon grafting	98	73		
Miller[22]	Primary suture	32	18		14
	Tendon grafting	10	7		3

results of 70 per cent. Results of primary tenorrhaphy have ranged from 5.6 per cent good results, reported by Foss Hauge[8] in 1951, to 86 per cent, reported by Posch.[28] In our series, 14 out of 32 cases, or 44 per cent, had flexion deficit of 1½ inches or more. Boyes[2] reports 51 per cent poor results in 89 cases of primary tenorrhaphy.

Tendons Cut in Their Digital Course, Severance of Flexor Profundus Intact Sublimis

Case 4. Male, age 14 years. Lacerated flexor tendon at distal interphalangeal crease, right index finger. Advancement operation, Bunnell No. 35 wire through drill hole in terminal phalanx (Fig. 10).

Comment

Tendons cut in their digital course. Severance of flexor profundus, intact sublimis.

Diagnostically there is a functioning proximal interphalangeal joint with loss of distal interphalangeal joint function. The profundus may be lacerated at the following levels: (1) At the distal flexion crease of the finger; (2) over the distal third of the middle phalanx of the finger; and (3) in the region of sublimis insertion.

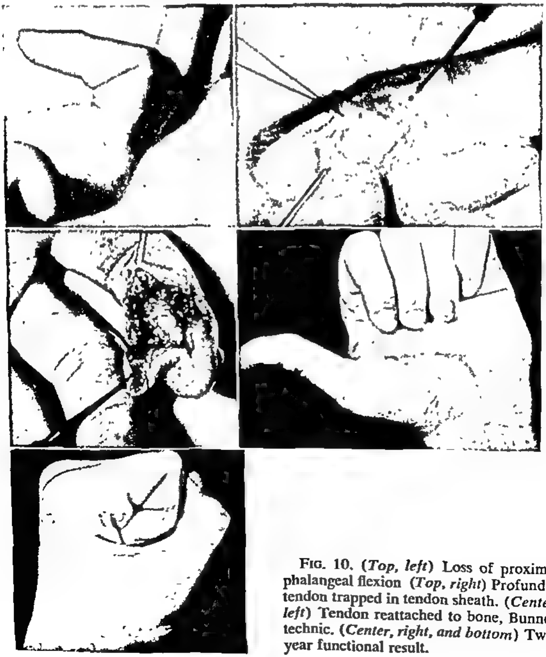


Fig. 10. (*Top, left*) Loss of proximal phalangeal flexion (*Top, right*) Profundus tendon trapped in tendon sheath. (*Center, left*) Tendon reattached to bone, Bunnell technic. (*Center, right, and bottom*) Two-year functional result.

Lacerations at the distal flexion crease of the finger may be treated by drawing the proximal tendon stump down to the distal attachment and fixing it in this position. It may be necessary to flex the wrist and the fingers to accomplish this advancement operation. Nichols[21,24] has reported successful results with this technic In our experience, the Bunnell pull-out wire technic has given the best results.

Lacerations of flexor tendons occurring over the distal third of the middle phalanx may be treated by (1) primary end-to-end suture; (2) tenodesis; (3) arthrodesis; and (4) tendon graft.

Primary tenorrhaphy may be done, conditions being favorable, if the suture line resulting from the repair is clear of the sublimis insertion. This may be accomplished by resecting a centimeter of tendon from the distal stump. Should the suture line be in the vicinity of a contused or a partially lacerated sublimis insertion, marked scarring may occur with resultant loss of function to a previously functioning proximal interphalangeal joint. On occasions tenolysis will bring about good functional return.

Tenodesis and Arthrodesis. Some surgeons feel that joint fixation will suffice and are content to perform a tenodesis or an arthrodesis. These are excellent operations and are especially useful in the injured hand already crippled by disease.

Tendon Graft. In lacerations at the site of sublimis attachment, the resultant tendon suture line will adhere, leaving a bulbous mass that will not glide. Here it is best to do primary tendon graft, utilizing palmaris longus or tendon slips from extensors of the toes

Occasionally it is possible to suture the profundus tendon secondarily if it has t
retracted out of the fork of the
However, more often the proximal
too thick and bulbous, requiring sa
too much length, or it has retracted
palm.

Primary tenorrhaphy is feasible, conditions being favorable for the lacerated:

1. *Flexor Pollicis Longus.* This tendon heals well. Mason[18] cautions about keeping the suture line away from the channel between the two sesamoid bones at the base of the thumb.

2. *Tendons in the Proximal Palm.* Here both sublimis and profundus tendons may be sutured and lumbrical muscle interposed between the two repaired tendons' suture lines.

3. *Tendons in the Carpal Tunnel.* Suture only the profundus tendons.

4. *Tendons in the Wrist.* Suture all tendons and nerves, leaving the volar carpal ligament open to avoid constriction and provide a better gliding surface.

SOURCE OF MATERIAL

The present study includes 125 patients operated upon at the Allentown (Pa.) General Hospital in the past 5 years and 300 cases studied previously and reported by me.[22] In reviewing my files, complete follow-up data are available in 125 cases. On those cases lost to complete follow-up, it will be possible to draw certain conclusions as to distribution, etiology, etc., from a review of available data on them.

Etiologic Factors in Injury. In reviewing causes of tendon laceration in the regions considered (Allentown, Pa., and Detroit, Mich.), essentially they are similar. Sixty per cent of the lacerations were incurred in the home as a result of accidents with bread slicers, broken drinking glasses, axes, windowpanes, meat grinders, wash-wringers, car and garage doors. Thirty per cent of the tendon lacerations were incurred in industrial accidents involving power saws, drill
presses, falling steel s or flying pieces
of steel. One per don lacerations
was due to sports baseball, foot-
all, hunting and y, such as see-
ws, swings, etc. ning 9 per cent
ulted from mpts, careless

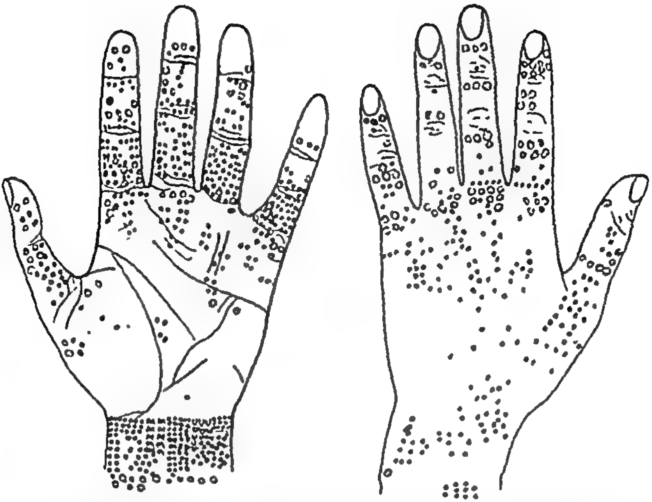


FIG. 11. Distribution of tendon lacerations, summary of 425 cases—524 flexors and 253 extensors. (*Left*) Flexor tendons over the wrist and the proximal palm involved in 38 per cent of cases; distal palm and proximal phalanx in 47 per cent of cases; middle and distal phalanges in 9 per cent of cases. Long (61), ring (58), index (56), little (45) involved in order named. Forty thumb flexors were lacerated—24 over proximal phalanx, 6 over distal phalanx and 10 in region of first metacarpal.

(*Right*) Distribution of 253 extensor tendon lacerations. Twenty per cent of all extensor tendon lacerations occurred on the dorsum of the wrist, whereas 37 per cent, or 93, tendons were lacerated on the dorsum of the hand. The rest of the lacerations were scattered over the digits: the index (30) and the long (17) fingers were involved most often in knuckle regions; the little (13) and the ring (10) fingers followed in frequency. There were 39 thumb extensors: 20 were lacerated over the first metacarpal, 18 over the proximal phalanx, and 1 over the distal phalanx.

Flexor and extensor tendon lacerations: M—median nerve laceration; U—ulnar nerve laceration.

horseplay with knives and other cutting instruments.

Distribution. An examination of Figure 11, in which the sites of flexor and extensor tendon lacerations are presented diagrammatically, discloses that the greatest number of lacerations occurred over the distal palm and the proximal phalangeal region or No Man's Land, while the least number, 2.5 per cent, or 13 tendons, were severed in their course over the terminal phalanx. In the case of the extensor tendons the highest percentage of lacerations, 52, occurred over the dorsum of the hand and the knuckle regions.

ANALYSIS OF RESULTS

A review of the results in 125 cases of flexor tendon lacerations in which adequate follow-up data are available is presented in

RESULTS OF TENORRHAPHY AND TENDON GRAFTING IN 125 CASES

Location	Primary Tendon Suture: Number of Cases	Good	Poor	Good Results Percentage	Second Tendon Grafting: Number of Cases	Good	Poor	Good Results Percentage
Wrist	25	23	2	92%				
Proximal palm	16	14	2	87%				
Distal palm Proximal phalanx	32	18	14	56%				
Middle phalanx	19	13	6	68%	9	6	3	70%
					1	1		
Distal phalanx	10	8	2	80%				
Thumb	11	7	4	64%				
Total	113	83	30		10	7	3	

Two cases had primary tendon grafting. Result: 1 good, 1 poor.

the table on page 150. It will be noted that lacerations involving the tendons at the level of the proximal phalanges gave the poorest results. The results improve as the tips of the fingers, the proximal palm and the wrist are approached. In our series, two cases were treated by primary tendon graft. One of these involving the long finger profundus and sublimis tendons resulted in excessive scarring and disruption of pulleys with inability to flex the finger within 2 inches of the distal flexion crease of the palm. The second case was that described under Case 3 and is reported as a good result.

Ten cases had delayed flexor tendon grafts in No Man's Land. Of these, 7 cases had good results. However, in analyzing these 7 cases, it may be stated that four of these had about 5° flexion deformity, while three had about 20° flexion deformity at the terminal interphalangeal joint This may be ascribed to some contracture of the graft. In general, no conclusions can be drawn from this small number of cases, but it would seem that the results from delayed grafting might be better than those from primary suture in No Man's Land.

Evaluation of cases followed was made after the methods described by Boyes.[3] Those cases in the "good group" were able to bring the pulp of the distal phalanx to within 3 to 4 cm. of the distal palmar crease. One hundred and thirteen cases were treated by primary suture with an over-all good-result percentage for the lacerations in the wrist, the proximal palm and the fingers of 65 per cent Complete follow-up data are available on only 10 secondary grafts for lacerations in No Man's Land, with good results in 70 per cent of these cases. Fifty-six per cent good results occurred in No Man's Land after primary suture.

SUMMARY

The best results in the treatment of lacerated tendons are dependent on an accurate diagnosis of the underlying pathologic condition and on careful attention to the details of repair. As a rule, the diagnosis of tendon and nerve injury is not difficult; a knowledge of the anatomy and the physiology of the hand is essential. In the treatment of tendon lacerations, each case must be considered as to its indication for primary repair, delayed

repair or grafting or primary grafting. In a high percentage of cases, careful mechanical cleansing and débridement of wounds less than 4 hours old and not heavily contaminated from human sources will heal by primary intention.

The apparent correlation between careful repair and good functional result dictates that meticulous attention to the details of repair, splinting and physiotherapy be the prime considerations. Repair can best be accomplished in the presence of a bloodless field and under general anesthesia or brachial plexus block. Intelligent splinting and physiotherapy presupposes a knowledge of the various phases of tendon healing.

A series of 125 cases of flexor tendon lacerations involving primary and secondary tendon procedure is presented. Three hundred additional cases of flexor and extensor tendon cases previously reported are reviewed partially as to distribution, etiology and follow-up results.

A review of our results confirms the facts already known and stated repeatedly. These are as follows:

1. Functional results are poorest in those tendons lacerated in No Man's Land and sutured primarily.

2. Primary suture can be accomplished successfully in this area if the wound is a cleanly incised one, is operated upon within 4 hours after injury, and is not contaminated by human sources.

3. Primary suture is feasible in the proximal palm, the carpal tunnel and the wrist and over extensor surfaces of the hand and the fingers. The thumb does lend itself to primary repair. However, as emphasized by Goldner,[9] if the suture line is directly opposite the metacarpophalangeal joint or opposite the proximal phalanx, the results are far from ideal.

4. In lacerations distal to the insertion of the sublimis, primary repair or advancement procedures will produce a good functioning finger.

5 Advancement procedures usually give good results if the injury is in the region of the distal flexion crease of the finger.

6. Primary tendon grafting is hazardous, for infection or aseptic necrosis resulting from error in judgment as to extent of tissue-bruising and contamination will result in irreparable loss.

REFERENCES

1. *Bell, J. L., Mason, M. L., and Allen, H. S.:* Management of acute crushing injuries of the hand and forearm over a 5-year period, 1948-1952, Am. J. Surg. 87:370-378, 1954.
2. Boyes, J. H.: Flexor tendon grafts in the fingers and thumb, J. Bone & Joint Surg. *32A:489-499, 1950.*
3. ———: *The immediate vs. delayed repair* of the digital flexor tendons, *Ann. West.* Med. & Surg. 1:145-152, 1947.
4. Bruner, J. M.: Problems of postoperative position and motion in surgery of the hand, J. Bone & Joint Surg. 35A:355-366, 1953.
5. Bunnell, S.: Surgery of the Hand, ed. 3, *Philadelphia*, Lippincott, 1956.
6. Couch, J. H.: Surgery of Hand, Some *Practical Aspects*, Toronto, Univ. Toronto Press, 1939.
7. Flynn, J. E.: Problems with *trauma to* hand, J. Bone & Joint Surg. *35A:132-140,* 1953.
8. Foss Hauge, M.: The results of tendon suture of the hand, Acta orthop. scandinav. *24:258-277, 1955.*
9. Goldner, J. L.: *Discussion* of the Albert Van't Hof and K. G. *Heiple paper entitled* "Flexor Tendon Injuries of the Fingers and Thumb," J Bone & Joint Surg. 40A:256-261, 1958.
10. Graham, W. G.: Flexor tendon grafts to *fingers and* thumb, J. Bone & Joint Surg. 29:553-559, 1947.
11. Koch, S. L.: The treatment of *compound* injuries and the infections resulting from them, ACOS Bulletin, pp. 1-8, March, 1932.
12. Koch, S. L., and Mason, M. L.: *Purposeful* splinting following injuries of the hand, Surg., Gynec. & Obst. 68:1-16, 1939.
13. ———: The technique of tendon suture, Surg., Gynec. & Obst. *56:1-39, 1933.*
14. Kyle, J. B., and Eyrebrook, A. L.: The surgical treatment in the hand, results obtained in a consecutive series of 67 cases, Brit. J. Surg. 41:502-511, 1954.

15. Littler, W. J.: Free tendon grafts in secondary flexor tendon repair, Am. J. Surg. 74: 315-321, 1947.
16. Mason, M. L.: Fifty years' progress in surgery of hand, Surg, Gynec. & Obst. 101: 541-564, 1955.
17. ———: Primary and secondary tendon suture, Surg., Gynec. & Obst. 72:392-402, 1940.
18. ———: The treatment of open injuries to the hand with particular reference to tendon repair, Postgrad. Med. 22:157-164, 1957.
19. ———: The treatment of open wounds of the hand, S. Clin. North America 28:4-26, 1948
20. Mason, M. L., and Allen, H. S.: The rate of healing of tendons, an experimental study of tensile strength, Ann. Surg. 113: 424-456, 1941.
21. Mason, M. L., and Bell, J. L.: The treatment of open injuries of the hand, S. Clin. North America 36:1337-1361, 1956.
22. Miller, Harry: Repair of severed tendons of the hand and wrist, Surg., Gynec. & Obst. 75:693-698, 1942.
23. Nichols, H. M.: A discussion of tendon repair, Ann. Surg. 129:223-234, 1949.
24. ———: Manual of Hand Surgery, p. 138, Chicago, Year Book Pub., 1955.
25. ———: Repair of extensor tendon insertions in the fingers, J. Bone & Joint Surg. 33A:836-841, 1951.
26. Peacock, E. E : Some Problems in Flexor Tendon Repair, presented before American Society for Surgery of Hand, New York City, Jan. 31, 1958.
27. Posch, J. L.: Primary tendon repair, S. Clin. North America 28:1323-1340, 1948.
28. ———: Secondary tenorrhaphies and tendon grafts in injuries to the hand, Am. J. Surg. 85:306-318, 1953.
29. Posch, J. L., Walker, P. J., and Miller, Harry: Treatment of ruptured tendons of the hand and wrist, Am. J. Surg. 91:669-681, 1956.
30. Pratt, D. R., Bunnell, S , and Howard, L. D.: Mallet finger, Am. J. Surg. 93:573-579, 1957.
31. Rank, B. K., and Wakefield, A. R.: Flexor tendon repair in the hand, Australian & New Zealand J. Surg. 21:135-139, 1951.
32. Siler, V.: Discussion of the J. E. Flynn paper entitled "Problems with Trauma to Hand," J. Bone & Joint Surg 35:251, 1953.
33. ———: Primary tenorrhaphy of the flexor tendons in the hand, J. Bone & Joint Surg. 32:218-224, 1950.
34. Sponsel, K. H.: Urgent surgery for finger flexor tendon and nerve lacerations, J.A.M.A. 166:1567-1572.
35. Strandell, Gunnar: Tendon grafts in injuries of the flexor tendons in the fingers and thumb, Acta chir. scandinav. 3:124-141, 1956.
36. Van't Hof, Albert, and Heiple, K. G : Flexor tendon injuries of fingers and thumb, J. Bone & Joint Surg 40A:256-261, 1958.
37. Winfield, J. M : Anatomic diagnosis of injuries of the hand, J.A.M.A. 116:1367-1370, 1941.

Acute Lesiones Aperte de Tendines Flexori del Mano

Summario in Interlingua

Notabile disveloppamentos ha occurrite durante le passate vinti-cinque annos in le correction de tendines a vaina lacerate. In despecto del augmento de nostre cognoscentias, le expertos in iste campo es sufficientemente objective pro conceder que le solution del problema es non ancora complete e que investigationes additional es indicate con respecto al reformation e al glissamento tendinose.

Le conditiones que es indispensabile al successo in le reparo de tendines flexori include le sequentes:

1. Le accurate determination del natura, del extension, e del loco del lesion.

2. Le plus meticulose attention prestate a omne detalios del raparo.

3. Perseverantia in le restauration del function.

Iste tres punctos merita esser sublineate individualmente. Como regula general, le diagnose de un lesion de tendine non es diffi-

cile. Familiaritate con le anatomia e le physiologia del mano es essential. In le tractamento de lacerationes del tendines, omne caso debe esser considerate individualmente quanto al indicationes pro un reparo primari, un reparo e graffage retardate, o un graffage primari. Le mesuras de un caute mundification mechanic sequite per un meticulose debridement del vulnere—providite que illo es presentate intra minus que quatro horas post su occurrentia e providite, in plus, que illo non es severmente contaminate per action human—resulta, in un alte procentage del casos, in un resanation primari.

Le apparente correlation inter le qualitate del reparo e le successo del restauration functional sublinea le importantia de prestar le plus meticulose attention a omne detalios del reparo, del uso de apparatos, e del initiation de mesuras physiotherapeutic. Le reparo se effectua le melio in un campo libere de sanguine e sub anesthesia general o con blocage del plexo brachial. Le exploitation intelligente del uso de apparatos e de mesuras physiotherapeutic presuppone le comprension del varie phases del resanation del tendines.

Altere conditiones que es necessari pro le successo de un sutura de tendine es le sequentes:

1. Le precise evalutation pre-operatori del viabilitate del pelle secundo le methodo a tourniquet proponite per Dr. Michael Mason.

2. Le correcte placiamento del incision, con omne possibile effortio de evitar contracturas per cicatrices, i.e. de facer le incision in plicas de flexion e parallel a lineas de fissura cutanee.

3. Le selection de un technica que produce le melior resultato functional in le caso particular. Nos ha obtenite le plus grande successos per medio del technica a filos de seta secundo Mason, sed nos ha *etiam* usate le technica a extrahibile filos metallic secundo Bunnell.

4. Grande attention prestate a immobilisar le parte lesionate pro permitter solmente un minimo de tension durante le periodo critic del resanation del tendine. In patientes pediatric isto significa le necessitate de un forte apparato que immobilisa le articulationes cubital e carpal.

Es presentate un serie de 125 casos de laceration de tendine flexori con le description del mesuras primari e secundari. Con respecto a 300 casos additional de laceration de tendine flexori e extensori que esseva discutite in un previe reporto, un revista partial es includite con detalios de distribution, etiologia, e observation consecutori. Cento dece-tres casos esseva tractate per sutura primari, con bon resultatos in lacerationes del carpo, del palma praximal, e del digitos amontante a 65 pro cento. Le bon resultatos amontava a 56 pro cento in le casos con sutura de tendines lacerate in le region supra le palma distal e le phalanges proximal. Solmente 10 tal casos, in que graffos secundari esseva inserite pro reimplaciar le tendines lacerate, esseva disponibile pro le obtention de complete datos de observation consecutori. In 70 pro cento de illos, le resultatos reportate esseva bon.

Un revista de nostre resultatos confirma le jam establite et repetitemente formulate factos que seque:

1. Le resultatos le minus satisfactori es obtenite quando suturas primari es usate in le reparo de tendines lacerate in le region supra le palma distal e le phalanges proximal.

2. Sutura primari de tendines flexori pote esser effectuate a bon successo in un micre numero de casos in que le vulneres es presente depost minus que quatro horas e in que le vulneres non es contaminate in consequentia de un action human.

3. Manovras de avantiamento produce bon resultatos in lacerationes que ha occurrite in le region del plica de flexion distal. In lacerationes del tendine profunde occurrente proxime al insertion del tendine sublime, avantiamento pote esser effectuate per excider un micre segmento del trunco

distal de maniera que le linea del sutura es ben distantiate ab le puncto de insertion del tendine sublime.

4. Reparo primari del tendine es effectuabile in le palma proximal, le tunnel carpal, le carpo, ■ le superficie extensori del mano e del digitos. Le flexor longe de pollice presta se a reparo primari con bon successo. Tamen, si le linea del sutura es directemente opposite al articulation metacarpophalangee ■ al base del phalange proximal, le resultatos certo non merita esser designate como ideal.

5. Graffage primari de tendine, usate como manovra routinari, es hasardose. Le judicamento clinic del chirurgo debe esser accurate quanto al grado de contusion de histo ■ al grado de contamination presente si ille vole effectuar graffage como manovra primari, proque si infection ■ necrosis aseptic superveni con resultante eschara de tendine, il es ben possibile que le causa es permanentemente perdite.

13

Finger Flexor Tenodesis*

DANA M. STREET, M.D., AND HARRY D. STAMBAUGH, M.D.

This procedure restores considerable function to the useless hands of a large group of quadriplegics. We report here our experiences and results in a series of twelve patients who have had a tenodesis of the flexor tendons in a paralyzed hand. Seventeen operative procedures were performed on these patients; three were repeat procedures, and two patients had a bilateral tenodesis. The patients in this study were male quadriplegics who had sustained acute traumatic lesions of the cervical cord with resultant myelopathy at the C-5 or the C-6 dermatome. The first tenodesis was done on October 20, 1949; the last, on December 23, 1957. The average follow-up period was 29 months.

HISTORY

In a review of the literature we have found few references to tenodesing the flexor tendons of the fingers to the distal forearm bones. Bunnell[2] discussed the tenodesing of the profundi tendons to the radius and incorporating the flexor pollicis longus in the tenodesis. Apparently he did not tenodese the sublimis but used the grafted sublimis tendon by tenodesis to the ulna to provide opposition of the thumb. He pointed out further that the brachioradialis might be anchored to the flexor tendons distal to the point of tenodesis to supply some degree of voluntary flexion to the fingers. Hendry[4] reported tenodesing the flexor and the extensor tendons in a completely flail hand. He fixed the thumb in forward abduction by placing a bone strut between the first and the second metacarpals and then passing the flexor sublimis and the profundus tendons through a hole in the radius proximal to the wrist. The extensor tendons next were passed through the same hole and sutured to the flexors. The grasp then is closed by supination of the forearm, when gravity extends the wrist, and relaxed by the tightening of the extensors on pronation. One case was reported in which the hand was flail except for a single extensor of the wrist, and after tenodesis the patient could maintain grasp but was unable to pick up objects.

Wilson[5] reports a series of four cases in which the tendons of the flexor digitorum profundi and the flexor pollicis longus were tenodesed to the distal radius. In one of his cases, the tendon of the index finger was not anchored but was sutured to a prolongation of the pronator teres to provide a voluntary flexion of this digit to be used as a "trigger finger." He reported useful function of all four tenodesed hands. One of us (HDS) has studied personally a case of Griffith's[3] in which a bilateral tenodesis was performed by anchoring the flexor digitorum profundus and the flexor pollicis longus to the radius. Opposition of the thumb was obtained by inserting a graft of the palmaris longus to the extensors of the thumb and tenodesing the proximal end of the graft to the distal ulna. An excellent result was obtained in both hands.

* From the Veterans Administration Medical Teaching Group Hospital, Memphis 15, Tenn.

INDICATIONS

Tenodesis of the flexor tendons of the fingers provides an automatic grasping mechanism when the wrist is extended voluntarily (see Fig. 7). Although the grasp that results is purely an automatic mechanical response with little, if any, of the finer movements of the normal hand being possible, nonetheless we have found it to be a most useful substitute for an otherwise functionless hand. The power of grasp is dependent, primarily, upon the remaining motor strength in the wrist extensors and, secondly, on the amount of checkreining to the distal tendons by the tendon anchorage. However, two other factors are important in determining the ultimate functional capacity of the hand. Mobility of the wrist and the metacarpophalangeal joints is essential, and a hand free of spasticity will lead to a better result.

The motor strength depends upon the number of functioning extensor motors remaining. A common site of injury of the cervical spine is at the C-5 to C-6 articulations. With complete interruption of the spinal cord at this level, little if any C-6 innervation remains. A large group of patients thereby is formed with only elbow flexors and wrist extensors. Most commonly, the brachioradialis and the extensor carpi radialis longus and brevis alone remain. Occasionally, only one extensor carpi radialis remains, and rarely is the extensor carpi ulnaris functioning. This is an insufficient number of motors to transfer for finger and thumb flexion and extension following arthrodesis of the wrist. Therefore, tenodesis is the best solution. The extensor mechanism can be strengthened by transfer of the brachioradialis in those cases in which the latter muscle is functional. The brachioradialis may also be transferred to the flexor group, distal to the point of tenodesis, to give a final voluntary impetus of prehension. A third use for this motor is by transferring to the flexor pollicis longus to provide voluntary independent lateral prehension. Fourthly, the brachioradialis may be transferred to the extensor pollicis longus to ensure the thumb's remaining outside the finger grasp. In none of our cases was there less than a full range of wrist extension against gravity.

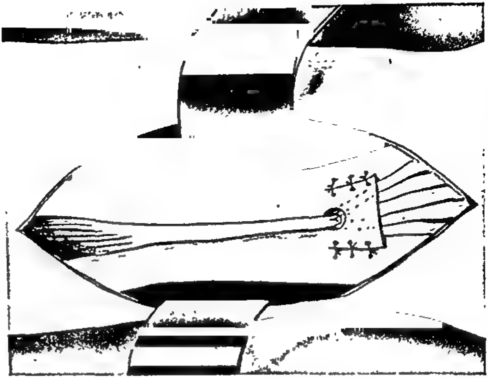
We have not utilized a definite unit for measuring the amount of checkreining of the flexor tendons but have relied on a clinical impression of the amount of finger flexion and tendon anchorage necessary to give the patient the best functioning grip. In most cases the fingertips have been brought into apposition to the thenar and the hypothenar eminences of the palm.

Our hospital is a quadri-paraplegia center, and we have had the opportunity to study mechanical gadgets devised in an attempt to restore some semblance of function to the paralyzed hand. The splint devised by Bisgrove[1] utilizes the same function of wrist extension to flex the fingers, and we have given it an extensive trial on a large group of patients. While the splints appear to be sound mechanically, we have found them to be unsatisfactory because (1) they must be in place, of course, to be used and thereby must be worn almost constantly; (2) they must be applied and adjusted by someone else, thus making the patient more dependent; (3) by their nature they are cumbersome, awkward to wear and difficult to adjust. Most of our patients would not wear these mechanical devices; therefore, we have abandoned them for the "built-in" tenodesis, which the patient always has with him and which requires no assistance or adjustment in its use.

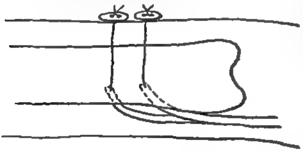
TECHNIC

Six different technics of anchoring the flexor tendons have been utilized in this series. In all cases the tendons were anchored to the distal volar radius, and exposure was gained through a longitudinal or L-shaped volar incision. The tendons of the flexor digitorum sublimis and profundus were anchored in all but one case, and in this case the profundus tendons alone were

Fig. 1. First technic. Severed flexor digitorum sublimis and profundus tendons placed beneath bony flap, anchored by suturing to proximal end of flexor carpi radialis tendon. Distal portion of flexor carpi radialis excised to avoid scarring with restriction of wrist extension.



anchored. In one of our cases the flexor pollicis longus also was tenodesed to the radius. The flexor carpi ulnaris was transferred to the extensor pollicis brevis, and the brachioradialis was attached to the flexor digitorum profundus and the flexor pollicis longus distal to the point of anchorage. In one of the bilateral patients, the brachioradialis tendons were sutured to the flexor pollicis longus tendons, and the extensor pollicis longus were tenodesed to the proximal phalanx. In another one of our cases, the flexor carpi radialis was transferred to the flexor pollicis longus. These transfers were done in an attempt to provide thumb opposition and a degree of refined function to the automatic hand.



In all cases it was considered important to

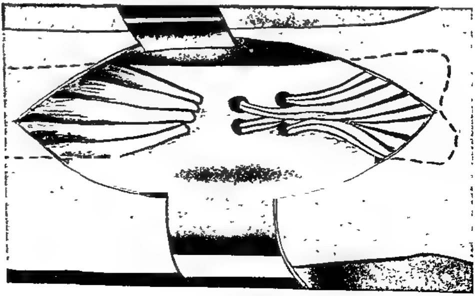


Fig. 2. Second technic. Sublimis and profundus tendons of the 4 fingers paired and held by wire sutures passing through one or several holes and tied over buttons on dorsum of wrist.

remove carefully all paratenon in order to secure solid anchorage. In many of the procedures, this was augmented further by placing bone dust from drilling, also bits of cancellous bone, between the tendons.

In seven hands a strut of cortical bone, either from the bone bank or that removed from the volar surface of the radius in fashioning a window, was placed beneath the tendons in contact with the volar surface of the radius and distal to the point of tendon anchorage (see Figs. 3 & 6). This bone bridge acts to increase the radius of the wrist joint by placing the tendons farther away from the axis of the wrist, thereby enhancing the strength of grasp.

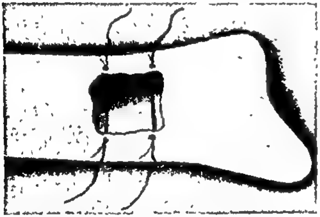
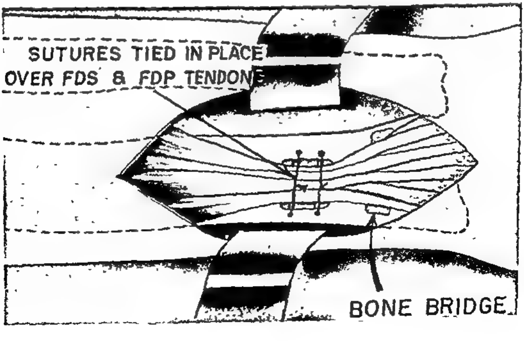


FIG. 3. Third technic. Tendons of sublimis and profundus were not severed but held in recess by silk sutures. This failed to give fixation in 2 out of 3 trials.

The technic of tenodesis originally employed, and used in two cases, consisted of elevating a bony tongue from the volar radius. The flexor tendons then were passed beneath it and anchored with a silk suture passed through a drill hole in the center of the tongue and tied over the proximal end of the severed flexor carpi radialis tendon (see Fig. 1). Anchorage has remained secure in this technic, but one patient later underwent reoperation because of too much slack in the tendons.

The next technic of tendon anchorage was utilized on three patients. The ends of the severed tendons were sutured with stainless-steel wire, and the tendons then were pulled into either a large single hole or multiple small drill holes in the radius. The steel-wire suture next was passed out to the dorsum of the forearm and anchored over buttons (see Fig. 2).

The third variation of tendon anchorage consisted of developing a bony window in the radius by removal of the volar cortex and cancellous bone beneath. Drill holes were placed through either side of the bony window and threaded with silk sutures,



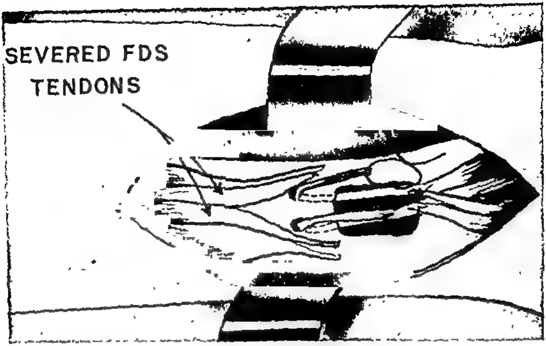


Fig. 4. Fourth technic. Profundus tendons to index and long fingers passed into window and out through separate more proximal drill holes, then sutured back on themselves. Tendons of ring and little fingers sutured to these. Only flexor digitorum profundus tendons anchored.

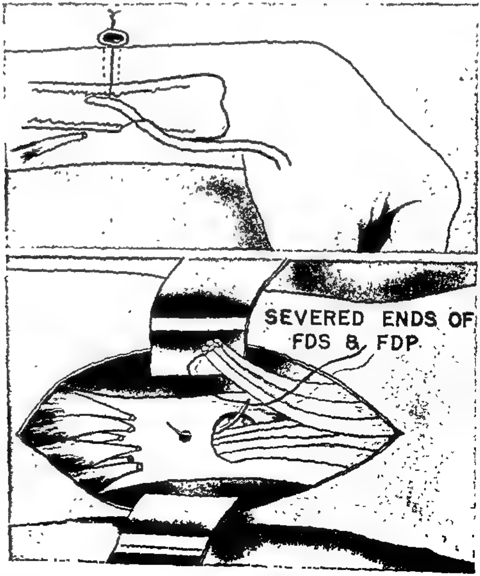


Fig 5. Fifth technic. Sublimis and profundus carried through window and a short distance up medullary canal by wire sutures tied over buttons on dorsum of wrist. Anchorage secure in cancellous bone.

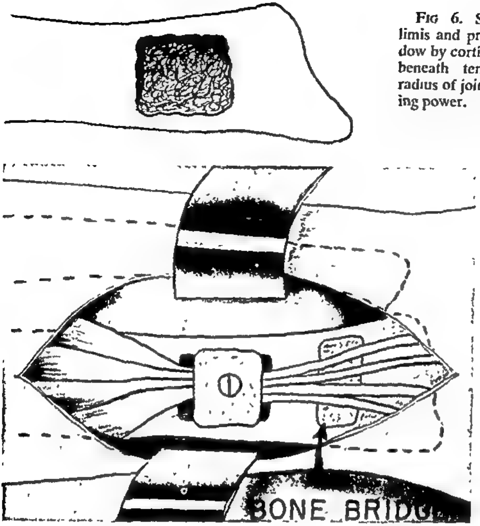
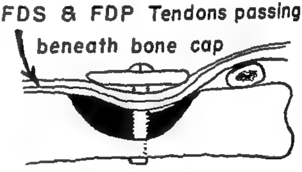


FIG 6. Sixth technic. Intact sublimis and profundus anchored in window by cortical bone cap. Bone bridge beneath tendons increases effective radius of joint motion, thereby increasing power.



which then were tied in place over the intact tendons (see Fig. 3). This technic was tried on three patients.

In our next technic, we anchored only the tendons of the flexor digitorum profundus. The tendon slips to the second and the third digits were passed through a bony window in the volar radius, then out drill holes proximal to the window, and doubled back and sutured to themselves. The slips to the fourth and the fifth digits were not passed through the window but were sutured to the sides of the slips of the second and the third digits. The muscle bellies of the flexor digitorum sublimis were brought down and anchored over the area of tenodesis (see Fig 4). This was the only case in our group to have the profundus alone anchored.

The fifth technic used in four instances consisted of threading the ends of the severed flexor tendons with stainless-steel wire sutures and passing the wire through a bony window in the volar aspect of the radius and out a volar drill hole just proximal to the window, using a curved needle. The wires are passed back through the drill hole and out a dorsal drill hole, with a straight needle, emerging on the dorsum of the wrist, where they are tied over buttons. When the wires are snugged down, the tendons are pulled into the window and up the medullary cavity

Fig. 7. Double exposure showing hand closed by power of wrist extensors and tightening of tenodesed finger flexors; opened by force of gravity and relaxed flexor tendons.

Fig 8. Tenodesis aids patient in self-care, allowing him to feed himself. Grasp of small objects such as a pen permits writing

Fig. 9. Tenodesis also aids patient in education and allows him to enjoy many comforts of life.

for a short distance. The bone chips, which were removed in fashioning the bony window, are placed about the tendons as they enter the defect in the radius (see Fig. 5). We do not use pull-out wires in this technic, but at the time that the hand is removed from the splint the wires are pulled up as far as possible and cut, and the ends are allowed to retract into the forearm.

Our latest technic of tendon anchorage again consists of fashioning a bony window in the volar radius. A piece of cortical bone from the bone bank is fashioned into a lid-cap to fit over the bony window, overlapping the margins of the window at each side to provide bony contact but allowing space for the tendons proximally and distally. The intact flexor tendons are placed in the depth of the window, and the lid-cap is anchored over them by passing a single Vitallium screw through to the dorsal radial cortex (see Fig. 6). Three hands have been treated by this method.

Just prior to anchoring the tendons, the fingers and the wrist are placed in flexion, and the tendons are secured by whatever technic is being utilized. An assistant maintains this degree of flexion during the remainder of the procedure and until a dorsal plaster-of-Paris splint has been applied. The skin incision is closed with either fine subcuticular wire or interrupted sutures of surgical cotton, and the hand is not disturbed for a period of 6 weeks. At the end of this time the splint is removed, and gradual rehabilitation and education of the hand are begun.

DISCUSSION AND RESULTS

We have been very encouraged by the useful function that the finger flexor tenodesis has afforded these heretofore useless hands. Of our twelve patients, ten have received an excellent functional result. Two have minor contractures of the interphalangeal joints which impede complete use of the grasp. At this time, further surgery is planned toward correcting the contractures, and we anticipate that these patients will gain full function of their tenodesed hands One of these patients was the one in whom only the profundus tendons were anchored, and the contractures which resulted involved the middle and the distal phalanges. We believe that the most useful hand will be obtained when the flexor digitorum sublimis and profundus tendons are both tenodesed

These patients have been able to perform many of the "activities of daily living," such as brushing and combing the hair, brushing the teeth, feeding themselves with knife, fork and spoon, and supporting a drinking glass or a cup (see Figs. 7-9). In addition, the more dexterous ones are able to hold playing cards and books, to propel a wheelchair, and to hold a pen and write. Many have learned to use a special "punch-stick" technic to operate a typewriter. In one of the patients with bilateral tenodesis, remarkable agility was attained in the use of his hands. He can pick up coins lying flat on a smooth surface and is very active in the occupational therapy department, where he has fashioned many articles in plastics and wood. The checkreining of the flexor tendons on this patient's second hand was purposely not as great as in the first hand, as we were attempting to give him a greater digitopalmar space for the grasping of larger objects. We believe that this is a very important point to consider in the patient who is to have a bilateral tenodesis.

We have not observed a tendency to stretching of the tendons as time and usage have progressed, as the tightness of grasp in our first case remains unchanged after almost 8 years. In one case which underwent reoperation, the cause of too much slack in the tendon was not the result of later stretching of the tendons but was an error in judging the amount of necessary checkreining at the time of original surgery.

We have found that the most satisfactory method of tenodesing the tendons is the technic employing stainless-steel wire sutures through the ends of the severed tendons and

then pulling the tendons into a defect in the radius and anchoring the wire sutures on the dorsum of the wrist, as illustrated in Figure 5. The lid-cap technic is easier to perform, and, we believe, is sound technically. However, it does involve the addition of a homograft of bank bone with the possibility of sequestration, and the healing time is prolonged, since bony union must take place for maximum fixation.

The third technic is the simplest and the easiest to perform, but it failed to give fixation in two of the three cases. Reoperation was necessary; therefore, the technic was abandoned.

CONCLUSION

We have reported twelve cases with seventeen procedures of tenodesing the finger flexor tendons in the paralyzed hand of young quadriplegic males. We have been very encouraged with the results obtained and feel the tenodesis is a superior method for affording useful function to these hands. Our results with six variations in technic of tendon anchorage is also presented.

REFERENCES

1. Bisgrove, J. G.: A new functional dynamic wrist extension—finger flexion hand splint; a preliminary report, J. A. Phys. & Ment. Rehabil. 8:162-163, 1954.
2. Bunnell, Sterling: Surgery of the Hand, ed. 3, p. 459, Philadelphia, Lippincott, 1956.
3. Griffith, B. H.: Personal communication.
4. Hendry, A. M.: Treatment of residual paralysis after brachial plexus injuries, J. Bone & Joint Surg. 31B:42-49, 1949.
5. Wilson, J. N.: Providing automatic grasp by flexor tenodesis, J. Bone & Joint Surg. 38A:1019-1024, 1956.

Tenodesis de Flexor Digital

Summario in Interlingua

Tenodesis de flexor digital esseva effectuate dece-septe vices in dece-duo quadriplegicos inter 1949 e 1957 con le resultato de un considerabile restauration del function manual. Previe reportos es pauco numerose, incluse reportos per S. Bunnell, A. M. Hendry, e J. W. Wilson.

Tenodesis de flexor provide un mechanismo de sasimento automatic. Le fortia de isto depende del remanente extensores carpal. Il existe un gruppo definite de patientes con vulneration del quinte e sexte vertebras cervical. Istes ha in function solmente le bicipite, le musculo brachioradial, e le longe e le breve extensor radial de carpo. In tal casos, tenodesis es le sol operation que pote esser de beneficio practic.

Esseva essayate sex typos de technica pro effectuar le plus firme tenodesis possibile. In le plus satisfacente (No. 5 del lista in le articulo), le tendines esseva dividite, e lor terminos distal esseva trahite a in un fenestra in le cortice radial volar e continuate un breve distantia in alto intra le canal medullar. Le suturas esseva effectuate a transverso un foramine plus proximal in le dorsal cortice radial e ligate super buttones al dorso del carpo. Es opinate que le resultante function es melior si non solmente le profundes sed etiam le sublimes es ancorate.

Le patientes del serie hic reportate ha obtenite un melior capacitate de tener brossa e pectine, brossa de dentes, cultello e furca, pluma, libros, etc. Illes etiam es capace a propeller lor chaise rolante. Le prime patiente del serie monstra nulle distension del tendines post octo annos de experientia postoperatori.

14

Tenosynovitis of the Hand and the Wrist: Carpal Tunnel Syndrome, de Quervain's Disease, Trigger Digit

PAUL R. LIPSCOMB, M.D.*

Numerous articles have been written about the various types of tenosynovitis or tendovaginitis that affect the hand and the wrist. It is beyond the scope of this chapter to discuss all the kinds and the locations that may be encountered, but the three most common syndromes will be considered. In previous articles,[21-23] the author has reviewed the literature and analyzed a total of 651 cases of nonspecific tenosynovitis and paratendinitis encountered at the Mayo Clinic from 1935 through 1948. In 1953, Bickel, Kimbrough and Dahlin,[2] reviewed 52 cases of tuberculous tenosynovitis that had been encountered at the Mayo Clinic. Pimm and Waugh[30] analyzed their experience with 44 patients who had 52 lesions of the tendon sheaths due to tuberculous tenosynovitis. In 1952, Burman,[6] in an extensive review of stenosing tendovaginitis of the dorsal and the volar compartments of the wrist, discussed cases in which he had seen this condition in almost every compartment of the wrist and referred to an extensive bibliography. Lapidus and Fenton[20] reported 423 instances of stenosing tendovaginitis of the wrist and the fingers in 369 patients who had 354 operations because of their disease.

In the last few years, small series of cases of tenosynovitis involving the sheath of the extensor carpi ulnaris tendon,[7] calcification about the flexor carpi ulnaris tendon,[29] calcareous tendinitis of a flexor tendon[11] and coccidioidal tenosynovitis[13] have been reported. Recently, too, there has been a tendency to include pigmented villonodular tenosynovitis,[34] also known as giant-cell tumor of the tendon sheath or xanthoma of the tendon sheath, with tenosynovitis.

In no previous articles covering an appreciable number of cases has the most common symptom complex due to tenosynovitis been mentioned. Only in the last few years has this syndrome been recognized in the vast majority of instances as being due primarily to tenosynovitis. I refer to the syndrome resulting from compression of the median nerve in the carpal canal. This has been designated as *median thenar neuritis, median neuritis, tardy median palsy, median neuropathy* and, most commonly, *the carpal tunnel syndrome*

During the past 2 years, from August 1, 1956, to August 1, 1958, I have treated surgically the hand and the wrist of 1 patient for tuberculous tenosynovitis, of 1 for noninfectious tenosynovitis due to a foreign body (rose thorn), of 4 for de Quervain's tendovaginitis, of 12 for trigger finger or thumb, and of 30 for carpal tunnel syndrome due to tenosynovitis.

* Section of Orthopedic Surgery, Mayo Clinic and Mayo Foundation, Rochester, Minn

TENOSYNOVITIS AS A CAUSE OF THE CARPAL TUNNEL SYNDROME

In 1865, Sir James Paget[31] related the history of a patient who suffered from compression of the median nerve at the wrist after a fracture of the lower end of the radius that repaired itself by an excessive quantity of new bone. In 1911, Hunt[14] cited 2 cases of thenar atrophy, which he stated must have been induced by continuous or frequently recurring pressure on the median nerve beneath the transverse carpal ligament. In 1913, Marie and Foix[27] reported the case of a woman, 80 years of age, who had what today would be called *carpal tunnel syndrome*. Necropsy revealed constriction of the median nerve beneath the transverse carpal ligament. In 1938, Moersch[29] reported the case of a stenographer, 39 years of age, who had atrophy of the thenar muscles and suggested, as did Marie and Foix,[27] that relief might be obtained by removal of the irritating factor or by surgical measures, such as section of the transverse carpal ligament.

In 1941, Woltman[40] reported 2 cases of median neuritis, one in a woman with acromegaly, which was improved after roentgen therapy to the pituitary region, and the second in a woman 71 years old. The second patient had complete anesthesia in the median distribution and motor palsy together with vesicles and ulcers of the index and the long finger of the affected hand. Within a few days after section of the transverse carpal ligament (the first instance of such treatment reported in the literature) the ulcers healed, pain disappeared, and eventually sensation and motor power returned. At that time Woltman correctly stated the cause of carpal tunnel syndrome:

> It is suggested that th [illegible] to [illegible] of [illegible] carpal bones and the anterior annular ligament. [illegible]. Section of the anterior annular ligament may be expected to afford relief.

In 1945, Zachary[18] reported 2 cases in which section of the transverse carpal ligament gave relief. In seeking the cause of compression of the median nerve in the carpal tunnel, he pleaded for careful investigation of the local condition in every case. In 1946, Cannon and Love[6] reported the first series of size—38 patients seen at the Mayo Clinic who had varying degrees of atrophy of the thenar eminence and muscle weakness. Decompression of the nerves of 9 of these patients was achieved by section of the transverse carpal ligament. In 1 of these 9 patients, a physician, the proliferated synovium was excised about the flexor pollicis longus tendon with a section of the ligament. One year later Brain and co-workers[3] reported on 6 patients treated surgically. In 1955, Love[26] reviewed an additional 57 cases in which decompression of the median nerve had been carried out between January 1, 1946, and December 31, 1954, at the Mayo Clinic. In 7 of these cases, an excessive amount of tissue was removed from the carpal canal. Love stated:

> Median neuritis is not too uncommon in association with rheumatoid arthritis and tenosynovitis of the flexor tendons of the fingers.

In 1950, Phalen and associates[34] postulated that the condition was much more common than was realized, and, in 1951, Phalen[33] stated:

> Any condition which might increase the volume of the structures contained within the carpal canal would tend to compress the nerve.

By 1957, Phalen and Kendrick[35] had reported on 71 patients who had been treated for compression neuropathy of the median nerve in the carpal canal and stated that, in most instances, this condition resulted from a chronic nonspecific synovitis involving the synovialis of the flexor tendons in the carpal canal. In 1952, Nissen[30] stated that, in most instances, the cause of carpal compression of the median nerve was a thickening of the flexor tendon sheaths (chronic nonspecific proliferative tenosynovitis) that reduced the

capacity of the carpal tunnel sufficiently to compress the median nerve.

The term *carpal tunnel syndrome* as now used denotes compression of the median nerve in the carpal tunnel from any cause; the list of causes reported is steadily growing, and, as might be imagined, the possibilities are legion. At the Mayo Clinic the syn-

FIG. 1. Carpal tunnel syndrome. (*Top*) This wrist shows a carpal tunnel syndrome; the wrist and the hand below do not. Note that when viewed in a tangential plane, there is definite swelling immediately above the transverse carpal ligament of the patient above. Thickening could be palpated in this patient.

(*Bottom, left*) Exposure of median nerve in the base of the palm. The palmaris brevis muscle and the transverse carpal ligament have been divided. The incision does not cross the proximal crease of the wrist. Constriction of the median nerve may be seen opposite the dark-appearing fibers of the severed palmaris brevis muscle. It is not necessary, and is even inadvisable, to carry the incision higher in the wrist unless the thickened synovial tissue (rarely indicated) is to be excised. Note thickened synovia, which almost completely obliterates vision of the flexor tendons.

(*Bottom, right*) Marked constriction of median nerve in a patient with carpal tunnel syndrome of long duration due to thickening and proliferation of the synovia surrounding flexor sheaths. A neuroma has formed proximal to the point of constriction. This patient had demonstrable anesthesia in her fingers and atrophy of the thenar musculature. The incision was extended proximally to facilitate excision of the proliferated synovium.

drome has been seen in association with nonspecific tenosynovitis, rheumatoid tenosynovitis, major trauma, occupational trauma, acromegaly, osteoarthritis, edema of the shoulder-hand syndrome, myxedema, edema of pregnancy, tuberculous tenosynovitis, and gout. A case of the last condition was reported recently by Ward, Bickel and Corbin.[44]

Present Concept of the Condition and the Diagnostic Aspects

In the first half of 1956, it gradually became apparent to me that the carpal tunnel syndrome was even more common than the literature indicated, and that the cause in the vast majority of cases was either a nonspecific or a rheumatoid tenosynovitis. Although the diagnosis was obvious when atrophy of the thenar eminence with muscular weakness or demonstrable anesthesia in the thumb, the index, the long and the radial half of the ring fingers, or both, were present, I decided that these objective findings really occurred only late in the disease process. It soon became evident, too, that most women past the menopause who complained of numbness and tingling in the fingers at night or after the slightest use of their hands were suffering from carpal tunnel syndrome, although no objective neurologic signs could be elicited. Electromyography and measurement of the conduction time in the peripheral portion of the median nerve proved to be of particular diagnostic help before objective neurologic signs were evident.* Previously, the diagnosis given many of these patients was thoracic outlet syndrome, writer's cramp and functional disturbances.

It gradually became evident, too, that often the patient who did not have objective neurologic evidence of the syndrome complained of numbness and paresthesia in all the fingers. These patients, who usually are women, commonly state that often they are awakened several times at night because of numbness, burning and pain that involve all the fingers. I would ask such a patient when she awakened the next night with such symptoms, to take the opposite hand and feel carefully the digits of the involved hand and let me know the following day which fingers actually were numb. Almost without exception, the patient would report for the first time that all but the little finger were involved. In about a third of the cases, the symptoms could be reproduced in the office by the wrist flexion test described by Phalen.[31] When such symptoms were reproduced, it could be demonstrated to the patient again that the little finger was not involved by the numbness, although she had maintained previously that all digits were affected.

It soon became evident, too, that on close examination of most of the patients with this syndrome, one could detect slight swelling or thickening about the flexor tendons just above the wrist when viewed in a tangential plane (Fig. 1, *top*). Deep pressure over the median nerve at the wrist often was painful, and occasionally in these cases Tinel's sign could be demonstrated.

Recently we decompressed the median nerve of several patients who did not have neurologic and electromyographic signs of carpal tunnel syndrome, because even the latter findings are comparatively late. In the majority of instances, the patients with minimal symptoms have been treated with at least temporary success by the injection of hydrocortisone into the carpal canal. If the symptoms recurred or were not relieved entirely after injection of hydrocortisone—and such was often the case—section of the ligament was advised.

Author's Series

From August 1, 1956, to August 1, 1958, I operated on 33 patients having carpal tunnel syndrome. During this period, several times this number of patients were operated on by colleagues in the orthopedic and the

* Electromyography was performed in many of the cases under discussion by Dr. E. H. Lambert and associates.

neurosurgical sections of the Mayo Clinic for this condition. At the time of operation on my patients, careful note was made with regard to the status of the underlying flexor synovialis, and specimens of synovia were removed for biopsy from each wrist operated on.

Cause of Tenosynovitis and Associated Conditions

In all but 3 patients in my series, the carpal tunnel syndrome was due definitely to tenosynovitis. In 1 of these 3, the condition was associated with chemical neuritis that had developed after local blocking of the median nerve several months previously. Another patient had a shoulder-hand syndrome with generalized edema of the hand and associated median neuritis, and in the third patient the carpal tunnel syndrome was the result of a blow over the heel of the hand that produced scarring about the nerve. Eventually, all 3 of these patients recovered satisfactorily.

Of the remaining 30 patients, 1 had severe pain of the causalgic type in both upper extremities. Examination before operation revealed thickening about the flexor tendons above the transverse carpal ligaments, and roentgenologic examination demonstrated rather marked degenerative changes of the carpal bones and of the cervical vertebrae. How much of this patient's discomfort was due to compression of the nerves at the wrists and how much to compression of the nerve roots as they left the cervical canal could not be ascertained. Although the patient received temporary relief of her pain after section of the transverse carpal ligaments and biopsy of the definitely thickened synovia, this relief, unfortunately, did not last. Recently she had extensive cervical laminectomy, but, when seen last, she still complained bitterly of burning, causalgialike pain in both hands. Of the remaining 29 patients with tenosynovitis causing compression of the median nerve in the carpal tunnel, all but 3 were women. The average age

AGE OF 29 PATIENTS WITH CARPAL TUNNEL SYNDROME

AGE	PATIENTS
20-29	1
30-39	2
40-49	8
50-59	10
60-69	3
70-79	3
80-89	1
90-100	1
Total*	29

* Of the 29 patients, 26 were women and 3 were men

of the patients was 55 years; the oldest was 90 years of age, and the youngest was 29 (table above). Approximately two thirds of the patients were in the fifth and the sixth decades of life.

Four of the 29 patients had rheumatoid tenosynovitis, but this disease probably was responsible for more of the cases than could be proved and than would be indicated by statistics. Jacobs and associates[15] also reported recently on a patient who had an operation for a carpal tunnel syndrome. Tenosynovitis developed in the flexor sheath of the right long finger 3 months later, and in another 3 months a full-blown rheumatoid arthritis developed.

Several of the patients in my series had associated trigger fingers, and one had de Quervain's disease, for which operation was performed, but a definite diagnosis of rheumatoid arthritis could not be established. Many patients gave a history of intermittent attacks of *bursitis of the shoulder, tennis elbows* or occasional swelling of 1 or 2 joints. The sedimentation rate of erythrocytes was not elevated significantly in those patients having early rheumatoid tenosynovitis. Jacobs and associates[15] made the same observation. One of my patients who had rheumatoid arthritis with tenosynovitis and

a carpal tunnel syndrome had bilateral Raynaud's phenomenon affecting her hands. Since the operation early in 1957, not only has this patient been relieved of her excruciating pain but the Raynaud phenomenon also has improved. The Raynaud phenomenon of this particular patient probably was on the basis of reflex vasomotor changes secondary to compression of the median nerve in the carpal canal.

One of the patients had bilateral carpal tunnel syndrome associated with myxedema. The symptoms were worse on the right than on the left. After incision of the transverse ligament on the right, at which time thickening of the synovialis was noted, immediate improvement occurred and, eventually, full recovery. With adequate therapy of the myxedema and decrease in this patient's generalized edema, the symptoms of the carpal tunnel syndrome on the left subsided gradually over a period of many months.

Number of Operations

In 21 of the 29 patients, bilateral operations were performed, and in 6 the operation was on the right wrist only and in 2 on the left wrist only. In 2 patients with long-standing atrophy of the thenar musculature, simultaneous transfer of the flexor sublimis tendon of the ring finger to the thumb, to restore opposition in the right hand, was carried out, using the Riordan technic.

Microscopic Findings

As had been pointed out by Phalen,[23] microscopic study of the synovia, even when definite gross thickening is present, may reveal little. As in other forms of tenosynovitis, the microscopic picture of the tenosynovitis of the carpal tunnel syndrome is going to vary from time to time, depending on the stage and the activity of the synovitis. The pathologic reports on the synovium submitted for microscopic study in my cases were often as follows:

(1) Myxomatous changes; (2) noninflammatory connective tissue; (3) fatty and fibrous tissue; (4) myxomatous fibrous tissue; (5) moderate fibrosis; (6) slightly inflamed synovial tissues; (7) fibrous proliferation with chronic inflammation; (8) chronic synovitis; (9) noninflammatory edematous synovial sheaths; and (10) chronic proliferative synovitis showing a few foci of lymphocytes and marked proliferation of synovial elements.

In spite of the microscopic findings, as mentioned previously, I am of the opinion that definite proliferation of the synovium was present in the carpal canal in 30 cases, and in some this was markedly excessive. In a few instances, the extensively thickened synovium was excised at the time of operation.

Anesthesia and Surgical Technic

General anesthesia was used in 17 and local anesthesia in 12 of the 29 patients in my series having tenosynovitis as the cause of their disease. In recent months, local anesthesia has been preferred. Five cubic centimeters of 2 per cent solution of lidocaine hydrochloride (Xylocaine) containing 3 minims of epinephrine solution (Adrenalin) per 30 cc. is injected into and about the median nerve 2 inches above the wrist. In most instances, injection at this level ensures a block of the palmar branch of the median nerve. The line of incision, which extends along the proximal half of the thenar crease and diagonally across the distal wrist crease, but not across the more proximal of the 2 main wrist creases, is infiltrated with 5 cc. of 1 per cent solution of Xylocaine containing the same proportion of epinephrine solution (Adrenalin).

With the tourniquet inflated, sharp dissection is used to section the palmaris brevis muscle and the transverse carpal ligament, which for practical purposes lie in the base of the palm. Care is taken to keep the dissection to the ulnar side of the nerve so as not to injure the motor branch. After section of the transverse carpal ligament and any tight fascial bands, the palmaris longus

neurosurgical sections of the Mayo Clinic for this condition. At the time of operation on my patients, careful note was made with regard to the status of the underlying flexor synovialis, and specimens of synovia were removed for biopsy from each wrist operated on.

Cause of Tenosynovitis and Associated Conditions

In all but 3 patients in my series, the carpal tunnel syndrome was due definitely to tenosynovitis. In 1 of these 3, the condition was associated with chemical neuritis that had developed after local blocking of the median nerve several months previously. Another patient had a shoulder-hand syndrome with generalized edema of the hand and associated median neuritis, and in the third patient the carpal tunnel syndrome was the result of a blow over the heel of the hand that produced scarring about the nerve. Eventually, all 3 of these patients recovered satisfactorily.

Of the remaining 30 patients, 1 had severe pain of the causalgic type in both upper extremities. Examination before operation revealed thickening about the flexor tendons above the transverse carpal ligaments, and roentgenologic examination demonstrated rather marked degenerative changes of the carpal bones and of the cervical vertebrae. How much of this patient's discomfort was due to compression of the nerves at the wrists and how much to compression of the nerve roots as they left the cervical canal could not be ascertained. Although the patient received temporary relief of her pain after section of the transverse carpal ligaments and biopsy of the definitely thickened synovia, this relief, unfortunately, did not last. Recently she had extensive cervical laminectomy, but, when seen last, she still complained bitterly of burning, causalgialike pain in both hands Of the remaining 29 patients with tenosynovitis causing compression of the median nerve in the carpal tunnel, all but 3 were women. The average age of the patients was 55 years; the oldest was 90 years of age, and the youngest was 29 (table above). Approximately two thirds of the patients were in the fifth and the sixth decades of life.

AGE OF 29 PATIENTS WITH CARPAL TUNNEL SYNDROME

AGE	PATIENTS
20-29	1
30-39	2
40-49	8
50-59	10
60-69	3
70-79	3
80-89	1
90-100	1
Total*	29

* Of the 29 patients, 26 were women and 3 were men.

Four of the 29 patients had rheumatoid tenosynovitis, but this disease probably was responsible for more of the cases than could be proved and than would be indicated by statistics. Jacobs and associates[15] also reported recently on a patient who had an operation for a carpal tunnel syndrome. Tenosynovitis developed in the flexor sheath of the right long finger 3 months later, and in another 3 months a full-blown rheumatoid arthritis developed.

Several of the patients in my series had associated trigger fingers, and one had de Quervain's disease, for which operation was performed, but a definite diagnosis of rheumatoid arthritis could not be established. Many patients gave a history of intermittent attacks of *bursitis of the shoulder, tennis elbows* or occasional swelling of 1 or 2 joints. The sedimentation rate of erythrocytes was not elevated significantly in those patients having early rheumatoid tenosynovitis. Jacobs and associates[15] made the same observation. One of my patients who had rheumatoid arthritis with tenosynovitis and

a carpal tunnel syndrome had bilateral Raynaud's phenomenon affecting her hands. Since the operation early in 1957, not only has this patient been relieved of her excruciating pain but the Raynaud phenomenon also has improved. The Raynaud phenomenon of this particular patient probably was on the basis of reflex vasomotor changes secondary to compression of the median nerve in the carpal canal.

One of the patients had bilateral carpal tunnel syndrome associated with myxedema. The symptoms were worse on the right than on the left. After incision of the transverse ligament on the right, at which time thickening of the synovialis was noted, immediate improvement occurred and, eventually, full recovery. With adequate therapy of the myxedema and decrease in this patient's generalized edema, the symptoms of the carpal tunnel syndrome on the left subsided gradually over a period of many months.

Number of Operations

In 21 of the 29 patients, bilateral operations were performed, and in 6 the operation was on the right wrist only and in 2 on the left wrist only. In 2 patients with longstanding atrophy of the thenar musculature, simultaneous transfer of the flexor sublimis tendon of the ring finger to the thumb, to restore opposition in the right hand, was carried out, using the Riordan technic.

Microscopic Findings

As had been pointed out by Phalen,[33] microscopic study of the synovia, even when definite gross thickening is present, may reveal little. As in other forms of tenosynovitis, the microscopic picture of the tenosynovitis of the carpal tunnel syndrome is going to vary from time to time, depending on the stage and the activity of the synovitis. The pathologic reports on the synovium submitted for microscopic study in my cases were often as follows:

(1) Myxomatous changes; (2) noninflammatory connective tissue; (3) fatty and fibrous tissue; (4) myxomatous fibrous tissue; (5) moderate fibrosis; (6) slightly inflamed synovial tissues; (7) fibrous proliferation with chronic inflammation; (8) chronic synovitis; (9) noninflammatory edematous synovial sheaths; and (10) chronic proliferative synovitis showing a few foci of lymphocytes and marked proliferation of synovial elements.

In spite of the microscopic findings, as mentioned previously, I am of the opinion that definite proliferation of the synovium was present in the carpal canal in 30 cases, and in some this was markedly excessive. In a few instances, the extensively thickened synovium was excised at the time of operation.

Anesthesia and Surgical Technic

General anesthesia was used in 17 and local anesthesia in 12 of the 29 patients in my series having tenosynovitis as the cause of their disease. In recent months, local anesthesia has been preferred. Five cubic centimeters of 2 per cent solution of lidocaine hydrochloride (Xylocaine) containing 3 minims of epinephrine solution (Adrenalin) per 30 cc. is injected into and about the median nerve 2 inches above the wrist. In most instances, injection at this level ensures a block of the palmar branch of the median nerve. The line of incision, which extends along the proximal half of the thenar crease and diagonally across the distal wrist crease, but not across the more proximal of the 2 main wrist creases, is infiltrated with 5 cc. of 1 per cent solution of Xylocaine containing the same proportion of epinephrine solution (Adrenalin).

With the tourniquet inflated, sharp dissection is used to section the palmaris brevis muscle and the transverse carpal ligament, which for practical purposes lie in the base of the palm. Care is taken to keep the dissection to the ulnar side of the nerve so as not to injure the motor branch. After section of the transverse carpal ligament and any tight fascial bands, the palmaris longus

tendon is severed at its insertion and allowed to retract, thereby preventing any constriction of the nerve by this structure. Usually, the point of constriction of the nerve is easily identified, and, if marked, saline neurolysis may be performed (Figs. 1, *bottom, left & right,* and 2). The underlying synovialis is always inspected, and a specimen is sent to the pathologic laboratory for microscopic section. The tourniquet is released, hemostasis secured, the wound closed, and a large compressive dressing applied to diminish edema. When both hands are operated on, the distal 2 phalanges of the fingers and the thumb usually are left free so as not to incapacitate the patient completely. In most instances, the patient leaves the hospital the following day.

Result of Operation

When the operation has been performed in the morning, many patients tell us in the afternoon that for the first time in many years they are able to hold a book or a magazine for more than a few minutes at a time without their fingers going to sleep. By the following morning, definite increase in sensation is noted by the majority of individuals. Others have told us a few days later that for the first time in many years they were able to write a letter at one sitting rather than in stages, as in the past. If definite anesthesia and muscle atrophy of long duration had been present, recovery was much slower, and, when atrophy had been present for several years, the surgeon should not expect recovery but rather would be justified in proceeding with a tendon transfer to restore opposition of the thumb.

All the patients operated on in the past 2 years on my service for tunnel carpal syndrome due to tenosynovitis, with the excep-

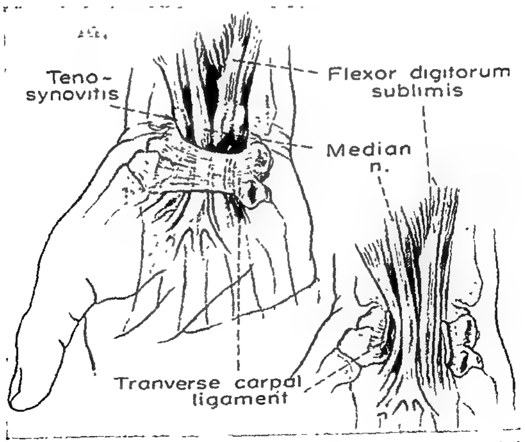


Fig 2. The anatomic aspects of the carpal tunnel syndrome and surgical method of releasing the compression of the nerve

tion of the one previously mentioned who also had the causalgia that did not respond to cervical laminectomy, have obtained complete relief or marked improvement of their symptoms. It is important to diagnose and treat this syndrome before demonstrable anesthesia and thenar atrophy occur.

STENOSING TENOSYNOVITIS AT THE RADIAL STYLOID PROCESS (DE QUERVAIN'S DISEASE)

When stenosis of a tendon sheath produces symptoms, some authors, Finkelstein,[11] Burman,[5] Lapidus,[19,20] Zadek[49] and Stein and associates[40] prefer the term *tenovaginitis* or *tendovaginitis* to *tenosynovitis;* yet, Dorland's Medical Dictionary[9] indicates that the 3 terms are synonymous. At any rate, when stenosis of the vaginal sheath is present, there is always, so far as my experience goes, associated tenosynovitis. Until the realization that the carpal tunnel syndrome was due in most instances to a tenosynovitis, it was my opinion—and that of most other writers—that the most common type of tenosynovitis involving the hand and the wrist was that which affected the common sheath of the abductor pollicis longus and the extensor pollicis brevis tendons at the radial styloid process, a condition still known as de Quervain's disease,[37] although it has been pointed out that de Quervain was not the first to describe this condition.

In the analysis of 651 cases of tenosynovitis previously mentioned by the author, it was thought that de Quervain's disease accounted for 34 per cent of the nonspecific types of tenosynovitis and paratendinitis of the wrist and the hand. There were 128 patients with de Quervain's disease in this group, and 42 had surgical correction of their condition. Since that time, large series of cases in which operations were performed by Lamphier,[18] Loomis,[25] Burman,[5] Lapidus and Fenton[20] and Stein and associates,[40] as well as others, have been reported. Prior to 1950, the diagnosis of stenosing tenosynovitis at the radial styloid process was rarely made except by orthopaedic surgeons and those particularly interested in surgery of the hand. In recent years, many patients have been referred with the correct diagnosis.

Anatomic and Physiologic Considerations

The tendons of the abductor pollicis and the extensor pollicis brevis muscles occupy the first compartment on the dorsum of the wrist. This compartment or canal is formed by a groove on the styloid process of the radius and is covered with a ligament lined with synovium that averages 1½ inches in length. As was pointed out by Bell and Bell,[1] in 1827, Wood,[47] in 1868, and Parsons and Robinson,[32] in 1898, the tendons of the abductor pollicis longus are composed of 2 to 4 slips in approximately three fourths of all dissected forearms in cadavers. This anatomic fact was apparently forgotten by most anatomists until Wagenseil,[42] in 1936, Lacey and co-workers,[17] Fenton and Lapidus[10] and Loomis[25] again called attention in the last decade to the fact that multiple insertions of the abductor pollicis longus tendon were normal rather than abnormal. Parsons and Robinson[32] also pointed out that the insertion of the extensor pollicis brevis varies greatly. As Loomis[25] and Bunnell[4] emphasized, the tendon of the extensor pollicis brevis muscle may be in a separate osseofibrous canal of the first compartment.

It is now generally recognized that chronic trauma, which often is in the form of prolonged exertion or unaccustomed muscular efforts, is responsible for the majority of cases of stenosing tenosynovitis at the radial styloid process. Direct injury seems to initiate the symptoms in some persons. As the inflammatory reaction progresses, the stenosis increases. Pathologic changes vary in degree and are dependent on the chronicity of the disease. The histologic features were illustrated in an article by the author[24] in 1951 and by Stein and associates[40] in the same year.

Symptoms and Signs

Pain is the predominant symptom and varies in degree with the severity of the inflammatory reaction. The patient usually is a woman. Most observers agree that the syndrome is three times as common among women as among men. Often the pain is of the neuritic type and may extend up the forearm or into the thumb. Swelling and tenderness over the radial styloid process usually can be demonstrated. The overlying skin may be slightly warmer than the skin elsewhere; it also may be red. Often the patient is disabled and may complain of dropping articles because of pain or insecure grip. Weakness of the affected wrist and hand results from the pain. Motion of the wrist and the thumb may be decreased, and radial contracture actually may be present to compensate for the constriction in the first dorsal compartment (Fig. 3, *left*). Roentgenograms usually do not show any evidence of abnormality. The one finding that is always present and is almost pathognomonic of the disease is a positive reaction to the test described by Finkelstein.[11] In this test, the patient's thumb is placed in the palm of his hand, and the examiner grasps the patient's fingers and forces the wrist into ulnar deviation. The pain over the radial styloid process is excruciating if stenosing tenosynovitis is present in this site.

Differential Diagnosis

Stenosing tenosynovitis at the radial styloid process must be distinguished from the various arthritides with which it is most often confused and also from neuritis involving the superficial branch of the radial nerve, a rare location for a neuritic process. In addition, fractures, sprains, avascular necrosis and cysts of the carpal bones, ganglia, senile processes arising from the capsule of the joints, and other forms of tenosynovitis must be distinguished from de Quervain's disease.

Treatment

If the disease is of short duration and fibrosis is not too far advanced, many pa-

Fig 3. Stenosing tenosynovitis at the radial styloid. (*Left*) Radial deviation (contracture) of the wrist in a patient having severe stenosing tenosynovitis at the radial styloid process (de Quervain's disease) of long duration. (*Right*) Exposure through a transverse incision of an abductor pollicis longus tendon having three slips; the fourth tendon is the extensor pollicis brevis. The dorsal carpal ligament that produced the stenosis has been excised.

tients respond to the injection of 15 to 25 mg. of hydrocortisone into the first dorsal compartment. Sometimes the injection has to be repeated on 2 or 3 occasions. If no relief is obtained from the hydrocortisone, if symptoms recur in spite of several injections, or if the disease is of long standing, surgical intervention should be carried out. This can be done after infiltrating the skin and the deeper tissues in the region of the radial styloid process with a solution of procaine or Xylocaine. I prefer a 1 per cent solution of the latter containing a few drops (3 minims per oz.) of epinephrine. A transverse incision about 1½ inches in length is made over the radial styloid process. The superficial branch of the radial nerve is exposed in the anatomic snuff box and is retracted gently toward the dorsum of the hand. The stenosed sheath of the abductor pollicis longus and the extensor pollicis brevis is probed and unroofed by severance of the dorsal carpal ligament a distance of about 1½ inches in a longitudinal direction (Figs. 3, *right* and 4). The surgeon must always determine whether or not the compartment is bifid, and, if it is, both divisions must be unroofed. As Loomis[25] pointed out, the incidence of this finding is so much greater than indicated by dissections on cadavers

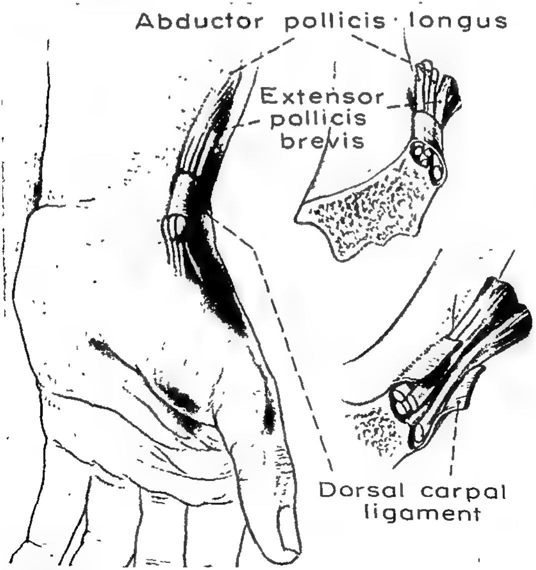
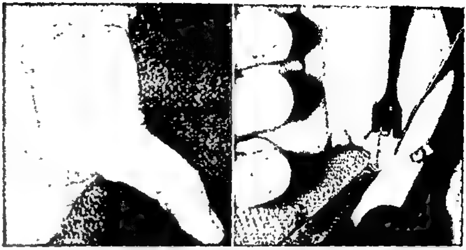


FIG. 4 Anatomic relationship and method of releasing the constricted tendons in the first dorsal compartment of the wrist in stenosing tenosynovitis at the radial styloid process (de Quervain's disease).



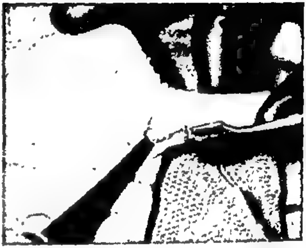


FIG. 5. Congenital stenosing tenosynovitis of the flexor pollicis longus tendon in a child. (*Top, left*) Prominence on the palmar surface of thumb at the level of the metacarpal head, hyperextension of the metacarpophalangeal joint and flexion of the interphalangeal joint. (*Top, right*) Same patient. Appearance of stenosed sheath with probe beneath the annular ligament. Note the "bunched-up" flexor pollicis longus tendon. Exposure was through a transverse incision. (*Bottom*) Same patient after excision of a portion of the stenosed annular ligament. Note the ability of the surgeon to extend completely the distal phalanx of the thumb.

that perhaps a bifid compartment should be considered to be a pathologic condition. Obviously, if the separate osseofibrous canal when present in the first compartment is not unroofed, the symptoms may not be relieved. A few milligrams of hydrocortisone solution usually is injected about the tendons before closure of the wounds. Only the skin is sutured. A fluff dressing to maintain the thumb in a position of abduction and opposition, and a splint to immobilize the wrist to some extent, make the patient comfortable for the first few days after operation.

The importance of a transverse incision, if minimal scarring is to be accomplished, and the avoidance of injury to the superficial branch of the radial nerve, if permanent anesthesia and perhaps a painful neuroma are to be avoided, cannot be overemphasized.

TRIGGER DIGITS (THUMB AND FINGERS)

Trigger, or snapping, finger or thumb is due to a narrowing of the sheath of the flexor tendon at the level of the metacarpal neck. An associated nodular enlargement of the tendon, which probably is secondary to the constriction, is seen in a number of cases. Trigger thumb in infants, which occurs almost equally in the two sexes, probably is different from the trigger thumb seen in adults, which occurs much more commonly in women.

TRIGGER THUMB IN CHILDREN

This condition, which often is seen in very young children, probably is congenital in origin in a number of instances. Although trigger thumb in children is not uncommon, trigger finger is extremely rare.[13] White and Jensen,[45] who reported 9 instances of trigger thumb in 7 children (infants), stated that 2 of the children had a definite family history of the condition and that the other 5 came from the same island—Kauai. Fahey and Bollinger,[9] in a review of trigger thumb in

adults and children, reported on 12 children with 15 involved thumbs and on 31 adults with stenosing tenosynovitis of the long flexor of the thumb. Sprecher[19] postulated that the position in which the infant holds his thumbs flexed, keeping the tendon sharply kinked over the proximal pulley, might produce sufficient trauma to cause the lesion. In children, extension of the thumb is usually blocked at 20° to 50° from complete extension, and a nodule, or thickening, can be palpated over the head of the first metacarpal. The child prefers to hold the thumb in a flexed position, and this is responsible for many cases of the so-called thumb-flexed hand. Often the cause of the flexed thumb is not understood, and Jahss[16] remarked in 1936, when he reported 10 cases, that he never yet had a patient referred to him with a correct diagnosis. Most of the trigger thumbs in children that I have seen were in infants, although 1 of the 3 children undergoing operation on my service for this condition in the past 3 years was 7 years of age.

If a child who holds the thumb in a flexed position cries when an attempt is made to extend the distal joint and a nodule can be felt in the region of the proximal pulley, the diagnosis is fairly certain. On attempted extension of the thumb, one may note hyperextension at the metacarpophalangeal joint and inability to extend the interphalangeal joint (Fig. 5, *top, left*). Treatment is surgical under general anesthesia and through a transverse incision between the 2 thumb creases at the level of the metacarpophalangeal joint. Care must be taken to avoid the volar digital nerves. The annular ligament is split longitudinally, and a probe is passed up and down the sheath to be sure that the tendon is freed (Fig. 5, *top, right*). If adhesions are present—and these have been noted at the site of stenosis in older children—the tendon should be dissected free (Fig. 5, *bottom*). Usually the nodular thickening of the tendon is not disturbed and tends to disappear with time About 5 mg. of hydrocortisone is injected about the tendon, especially if any scarring is noted. Results in almost all instances are satisfactory.

Trigger Finger and Thumb in Adults

Most writers who have analyzed large series of cases of trigger digits in adults have found that the thumb was involved most frequently. Next in order was the ring finger. Close behind was the long finger, next the little and last the index finger. Most observers have noted that among adults the ratio of females to males with snapping thumbs is approximately 4 to 1. Although Lapidus and Fenton[20] found almost the same incidence of trigger digits other than the thumb in males and females, most authors have reported a preponderance among females.

The snapping, or trigger, mechanism which often the adult can demonstrate to the examining physician is due to narrowing of the sheath of the flexor tendon, nodular enlargement of the tendon, or both. Free passage of the tendons is blocked, and, as the tendon passes the site of obstruction, a click, or snap, often is produced. Although the click may seem to be produced in the finger itself, almost always the pathologic process is located at the level of the metacarpal head, where a reinforcement of deep fascia forms the proximal annular ligament or pulley in the sheath of the flexor tendon. Although the thumb has only 1 long flexor tendon, this passes through a narrow unyielding sheath on the palmar surface at the neck of the first metacarpal. The sesamoids are located at this level, and the sheath is narrowest at this point.

If the annular ligament is pressed against the tendon by hard objects, such as the handles of scissors, pruning shears or other tools, repeated movements of the fingers or the thumbs may cause the onset of irritative phenomena. The irritation causes exudation, thickening of the tendon sheath and tendons just above and at the level of the sheath, and

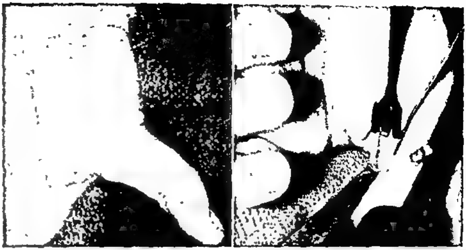


FIG. 5. Congenital stenosing tenosynovitis of the flexor pollicis longus tendon in a child. (*Top, left*) Prominence on the palmar surface of thumb at the level of the metacarpal head, hyperextension of the metacarpophalangeal joint and flexion of the interphalangeal joint. (*Top, right*) Same patient. Appearance of stenosed sheath with probe beneath the annular ligament. Note the "bunched-up" flexor pollicis longus tendon. Exposure was through a transverse incision. (*Bottom*) Same patient after excision of a portion of the stenosed annular ligament. Note the ability of the surgeon to extend completely the distal phalanx of the thumb.

that perhaps a bifid compartment should be considered to be a pathologic condition. Obviously, if the separate osseofibrous canal when present in the first compartment is not unroofed, the symptoms may not be relieved. A few milligrams of hydrocortisone solution usually is injected about the tendons before closure of the wounds. Only the skin is sutured. A fluff dressing to maintain the thumb in a position of abduction and opposition, and a splint to immobilize the wrist to some extent, make the patient comfortable for the first few days after operation.

The importance of a transverse incision, if minimal scarring is to be accomplished, and the avoidance of injury to the superficial branch of the radial nerve, if permanent anesthesia and perhaps a painful neuroma are to be avoided, cannot be overemphasized.

TRIGGER DIGITS (THUMB AND FINGERS)

Trigger, or snapping, finger or thumb is due to a narrowing of the sheath of the flexor tendon at the level of the metacarpal neck. An associated nodular enlargement of the tendon, which probably is secondary to the constriction, is seen in a number of cases. Trigger thumb in infants, which occurs almost equally in the two sexes, probably is different from the trigger thumb seen in adults, which occurs much more commonly in women

TRIGGER THUMB IN CHILDREN

This condition, which often is seen in very young children, probably is congenital in origin in a number of instances. Although trigger thumb in children is not uncommon, trigger finger is extremely rare.[13] White and Jensen,[45] who reported 9 instances of trigger thumb in 7 children (infants), stated that 2 of the children had a definite family history of the condition and that the other 5 came from the same island—Kauai. Fahey and Bollinger,[9] in a review of trigger thumb in

adults and children, reported on 12 children with 15 involved thumbs and on 31 adults with stenosing tenosynovitis of the long flexor of the thumb. Sprecher[39] postulated that the position in which the infant holds his thumbs flexed, keeping the tendon sharply kinked over the proximal pulley, might produce sufficient trauma to cause the lesion. In children, extension of the thumb is usually blocked at 20° to 50° from complete extension, and a nodule, or thickening, can be palpated over the head of the first metacarpal. The child prefers to hold the thumb in a flexed position, and this is responsible for many cases of the so-called thumb-flexed hand. Often the cause of the flexed thumb is not understood, and Jahss[16] remarked in 1936, when he reported 10 cases, that he never yet had a patient referred to him with a correct diagnosis. Most of the trigger thumbs in children that I have seen were in infants, although 1 of the 3 children undergoing operation on my service for this condition in the past 3 years was 7 years of age.

If a child who holds the thumb in a flexed position cries when an attempt is made to extend the distal joint and a nodule can be felt in the region of the proximal pulley, the diagnosis is fairly certain. On attempted extension of the thumb, one may note hyperextension at the metacarpophalangeal joint and inability to extend the interphalangeal joint (Fig. 5, *top, left*). Treatment is surgical under general anesthesia and through a transverse incision between the 2 thumb creases at the level of the metacarpophalangeal joint. Care must be taken to avoid the volar digital nerves. The annular ligament is split longitudinally, and a probe is passed up and down the sheath to be sure that the tendon is freed (Fig. 5, *top, right*). If adhesions are present—and these have been noted at the site of stenosis in older children—the tendon should be dissected free (Fig. 5, *bottom*). Usually the nodular thickening of the tendon is not disturbed and tends to disappear with time About 5 mg. of hydrocortisone is injected about the tendon, especially if any scarring is noted. Results in almost all instances are satisfactory.

Trigger Finger and Thumb in Adults

Most writers who have analyzed large series of cases of trigger digits in adults have found that the thumb was involved most frequently. Next in order was the ring finger. Close behind was the long finger, next the little and last the index finger. Most observers have noted that among adults the ratio of females to males with snapping thumbs is approximately 4 to 1. Although Lapidus and Fenton[20] found almost the same incidence of trigger digits other than the thumb in males and females, most authors have reported a preponderance among females.

The snapping, or trigger, mechanism which often the adult can demonstrate to the examining physician is due to narrowing of the sheath of the flexor tendon, nodular enlargement of the tendon, or both. Free passage of the tendons is blocked, and, as the tendon passes the site of obstruction, a click, or snap, often is produced. Although the click may seem to be produced in the finger itself, almost always the pathologic process is located at the level of the metacarpal head, where a reinforcement of deep fascia forms the proximal annular ligament or pulley in the sheath of the flexor tendon. Although the thumb has only 1 long flexor tendon, this passes through a narrow unyielding sheath on the palmar surface at the neck of the first metacarpal. The sesamoids are located at this level, and the sheath is narrowest at this point.

If the annular ligament is pressed against the tendon by hard objects, such as the handles of scissors, pruning shears or other tools, repeated movements of the fingers or the thumbs may cause the onset of irritative phenomena. The irritation causes exudation, thickening of the tendon sheath and tendons just above and at the level of the sheath, and

effusion into the sheath. As the discrepancy between the tendons and the sheath gradually becomes more marked, locking occurs, and the tendon cannot be pulled through the sheath without extrinsic assistance. The extensors of the fingers and the thumb are weaker than the flexors, and, as a rule, locking takes place when the finger is in flexion. The patient may demonstrate not only the snap, or click, but also impaired extension or a temporary flexion deformity (Fig. 6, *left*).

As would be expected, the right hand is involved more frequently than the left. In approximately 15 per cent of the patients, more than 1 digit is involved. Trigger fingers or thumbs in multiple denominations are encountered more often in patients who have rheumatoid arthritis than in other persons. Several of our patients who have had carpal tunnel syndromes have had operations for trigger fingers either at the same time or later.

If symptoms are of short duration, the locking and the inflammatory changes may be relieved by the injection of hydrocortisone into the sheath. Severe pain is not a prominent feature of the syndrome of trigger fingers or thumbs (Figs. 6, *right*, and 7). If symptoms have been present for some time, or the condition does not respond to the injection of hydrocortisone, the treatment is surgical excision of the constricted part of the tendon sheath, including the annular ligament or proximal pulley.

Excision is performed through a transverse incision parallel to the crease in the distal portion of the palm or the base of the thumb, as the case may be. Caution must be observed, particularly in the case of the thumb, not to injure the digital nerves. Graham[12] stated that he had treated many patients with trigger fingers, especially the long and the ring fingers, by subcutaneous sectioning of the annular ligament. I tried this in 2 cases, and, although it worked satis-

FIG 6 Trigger finger in an adult (*Left*) The right ring finger is locked temporarily in flexion because of stenosis of the annular ligament or pulley at the level of the fourth metacarpal head (*Right*) Appearance at time of operation Note the transverse incision carried parallel to the distal palmar crease and the apparent bulbous enlargement of the flexor tendons caused by the "bunching up" of the tendons just proximal to the point of stenosis of the sheath (Lipscomb, P. R.: GP 15:101)

factorily, I still prefer, under local anesthesia, to make a small transverse incision to ensure that there is no injury to digital nerves. The wound can be closed with 2 or 3 sutures and the patient treated on an outpatient basis.

Nine adults have been operated on during the past 2 years for trigger fingers or thumb on my service. Seven of these were women and 2 were men. The average age was 56½ years. One of the women had bilateral sectioning of the proximal annular ligaments of the long and the ring fingers, and 1 had an associated carpal tunnel syndrome that was operated on at the same time. Another patient with carpal tunnel syndrome in the past 2 years also has had locking of the right long finger and both thumbs; so far this has been treated successfully with injections of hydrocortisone.

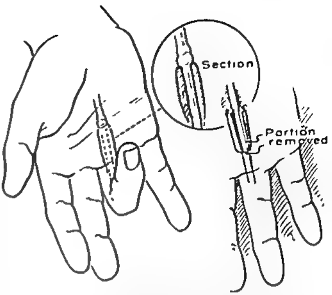


FIG. 7. Diagrammatic sketch of the condition and the surgical method of releasing the stenosis of the sheath for a trigger finger. (Lipscomb, P. R.: GP 15:101)

COMMENT

Of the 3 most common types of tenosynovitis affecting the hand and the wrist, 2 produce severe pain and 1 produces minimal pain but annoying locking. Two of the syndromes are primarily the result of stenosis of the sheath, and 1 is the result of proliferation of the synovium. Pain in the carpal tunnel syndrome is due to secondary compression of the median nerve. Pain in stenosing tenosynovitis at the radial styloid process may be due to the close proximity of the overlying superficial branch of the radial nerve. In several instances my colleagues and I have seen thickening of this nerve and evidence of irritative phenomena about the nerve. When pain is present in trigger fingers, it may be explained on the basis of the relationship of the volar digital nerves to the tendon sheath. All these syndromes, with the exception of trigger thumb in children and perhaps trigger fingers in adults, are seen predominantly in women in the fifth and the sixth decades of life.

In the vast majority of instances in the past, the condition of stenosing tenosynovitis at the radial styloid process and the trigger digit in adults was considered to be due to repeated trauma. There is no doubt that minor trauma does play a part in the production of symptoms in all 3 syndromes (carpal tunnel syndrome, de Quervain's disease and trigger digit), since the condition is seen more frequently in the right hand than in the left. However, the frequency in women in the decades mentioned cannot be explained entirely on this basis. If trauma were the most prominent factor in the production of these symptoms, a preponderance of males affected would be expected, and probably of males in the third and the fourth decades of life. Bunnell[4] has stated that ulnar angulation of the wrist is a little more marked in women than in men, and that this angulation may be a factor in the production of stenosing tenosynovitis at the radial styloid process. It is conceivable that other anatomic and perhaps physiologic factors may make the female more susceptible to the production of tenosynovitis.

It is interesting to note that a number of patients with the carpal tunnel syndrome and trigger digits have associated rheumatoid arthritis. Only recently I saw a woman in

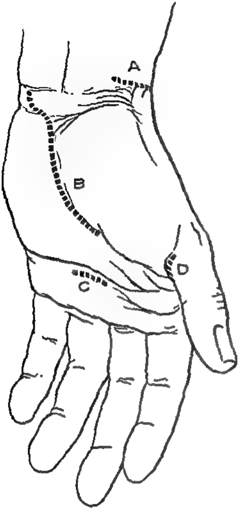


FIG. 8. Correct location of incisions for release of constrictions in (A) stenosing tenosynovitis at the radial styloid process (de Quervain's disease); (B) carpal tunnel syndrome; (C) trigger digit (ring finger); and (D) trigger thumb.

the sixth decade of life who had been operated on a few days previously for a carpal tunnel syndrome with relief of symptoms referable to the median nerve. However, acute de Quervain's stenosing tenosynovitis then developed and was relieved by an injection of hydrocortisone.

As previously mentioned, several patients have had carpal tunnel syndromes and trigger digits. A careful review of the history of these patients disclosed that some had had repeated attacks of so-called bursitis or calcific tendinitis of the musculotendinous cuff of the shoulder, lateral epicondylitis (tennis elbow), trochanteric bursitis and, occasionally, 1 or 2 attacks of unexplained synovitis of joints.

When the age and the sex of the patients involved are noted and it is realized that, without a doubt, tenosynovitis is associated with rheumatoid arthritis in some cases, one cannot help but wonder if this disease or a similar condition in its subclinical form is not much more prominent than is realized The blood sedimentation rate is a gross test and probably does not become elevated in the vast majority of instances of rheumatoid arthritis unless the synovium is involved severely or in many locations.

One hesitates to use the term *collagen disease* or *fibrous tissue dysplasia* because of its ambiguity, but often the 3 forms of tenosynovitis under discussion fall somewhere in this classification. I suspect that in many cases, carpal tunnel syndrome, trigger finger and de Quervain's disease are either associated with rheumatoid arthritis or allied to it.

All 3 of the syndromes respond favorably to injections of hydrocortisone into the synovial sheaths, when mild or of short duration, and to release of constriction of tendons or nerves and to sectioning of overlying dense ligaments in the other cases. In all 3 instances operation is simple and can be carried out in a few minutes' time with the use of local anesthesia and a bloodless field supplied by pneumatic tourniquet. The incisions should be made in correct lines (Fig. 8), and the surgeon should have a clear, concise knowledge of the anatomic factors involved. Most of these patients may be released from the hospital on the day of operation or the day after. Almost all patients suffering from the 3 syndromes can be offered relief of symptoms

SUMMARY

Attention is called to the frequent occurrence of the carpal tunnel syndrome, de Quervain's disease and trigger digits as the result of tenosynovitis. In all 3 conditions, women are affected more often than men, and all 3 conditions are seen most commonly

in patients in the fifth and the sixth decades of life. The right hand or wrist is involved more frequently than the left. Although occupational factors probably play a part in the production of the tenosynovitis and the symptoms of all 3 syndromes, other factors or diseases related to rheumatoid arthritis play a part. Spontaneous recovery may occur, and all 3 conditions may respond to injection of hydrocortisone into the synovial sheaths. The most conservative treatment for many patients is operative release of the constricted tendons or nerve. Incisions in line with the thenar crease in cases of the carpal tunnel syndrome, transverse incisions at the radial styloid process for de Quervain's stenosing tenosynovitis, and transverse incision in line with the creases at the base of the thumb or in the palm for stenosing tenosynovitis of the flexor sheaths of the digits are most important. The use of hydrocortisone about the tendons at the time of operation, biopsy of the synovium in every case, suturing of the skin only, splinting for a few days until the reaction from operation has subsided and then early mobilization also is important in the successful treatment.

REFERENCES

1. Bell, John, and Bell, Charles: The Anatomy and Physiology of the Human Body, ed. 5 (American), vol. 1, p. 214, New York, Collins & Co., 1827.
2. Bickel, W. H., Kimbrough, R. F., and Dahlin, D. C: Tuberculous tenosynovitis, J.A.M.A. 151:31, 1953.
3. Brain, W. R., Wright, A. D., and Wilkinson, M.: Spontaneous compression of both median nerves in carpal tunnel: 6 cases treated surgically, Lancet 1:277, 1947.
4. Bunnell, Sterling: Surgery of the Hand, ed. 3, Philadelphia, Lippincott, 1956.
5. Burman, Michael: Stenosing tendovaginitis of the dorsal and volar compartments of the wrist, A.M.A. Arch. Surg 65:752, 1952.
6. Cannon, B. W., and Love, J. G.: Tardy median palsy; median neuritis, median thenar neuritis amenable to surgery, Surgery 20:210, 1946.
7. Dickson, D. D., and Luckey, C. A.: Tenosynovitis of the extensor carpi ulnaris tendon sheath, J. Bone & Joint Surg. 30A:903, 1948.
8. Dorland, W. A. N.: The American Illustrated Medical Dictionary, ed. 22, Philadelphia, Saunders, 1951.
9. Fahey, J. J., and Bollinger, J. A.: Trigger-finger in adults and children, J. Bone & Joint Surg. 36A:1200, 1954.
10. Fenton, R. L., and Lapidus, P. W.: An anatomical study of the abductor pollicis longus and extensor pollicis longus and brevis, Bull. New York Hosp. Joint Dis. 14:138, 1953.
11. Finkelstein, Harry: Stenosing tendovaginitis at the radial styloid process, J. Bone & Joint Surg. n.s. 12:509, 1930.
12. Graham, Walter: Personal communication to the author.
13. Hodgins, T. E., and Lipscomb, P. R.: Bilateral trigger fingers in a child: report of case, Proc. Staff Meet., Mayo Clin. 31: 279, 1956.
14. Hunt, J. R.: The thenar and hypothenar types of neural atrophy of the hand, Am. J. M. Sc. 141:224, 1911.
15. Jacobs, J. H., Hess, E. V., and Beswick, Isobel P.: Rheumatoid arthritis presenting as tenosynovitis, J. Bone & Joint Surg. 39B:288, 1957.
16. Jahss, S. A.: Trigger finger in children, J.A.M.A. 107:1463, 1936.
17. Lacey, Thomas, 2nd, Goldstein, L. A., and Tobin, C. E.: Anatomical and clinical study of the variations in the insertions of the abductor pollicis longus tendon, associated with stenosing tendovaginitis, J. Bone & Joint Surg. 33A:347, 1951.
18. Lamphier, T. A., Long, N. G., and Dennehy, Timothy: De Quervain's disease: analysis of 52 cases, Ann. Surg. 138:832, 1953.
19. Lapidus, P. W.: Stenosing tenovaginitis, S. Clin. North America 33:1317-1347, 1953.
20. Lapidus, P. W., and Fenton, Richard: Stenosing tendovaginitis at the wrist and fingers: report of 423 cases in 369 patients with 354 operations, A.M.A. Arch. Surg. 64:475, 1952.
21. Lipscomb, P. R.: Chronic nonspecific tenosynovitis and peritendinitis, S. Clin. North America, 24:780-797, 1944.
22. ———: Non-suppurative Tenosynovitis: A Clinical and Pathologic Study. Thesis, Graduate School, University of Minnesota, 1942.

23. Lipscomb, P. R.: Nonsuppurative tenosynovitis and paratendinitis, Am. Acad. Orthop. Surgeons, Lect. 7:254-261, 1950
24. ———: Stenosing tenosynovitis at the radial styloid process (de Quervain's disease), Ann. Surg. 134:110, 1951.
25. Loomis, L. K.: Variations of stenosing tenosynovitis at the radial styloid process, J. Bone & Joint Surg. 33A:340, 1951.
26. Love, J. G.: Median neuritis or carpal tunnel syndrome: diagnosis and treatment, North Carolina M. J. 16:463, 1955.
27. Marie, Pierre, and Foix: Atrophie isolée de l'éminence thénar d'origine névritique: rôle du ligament annulaire antérieur du carpe dans la pathogénie de la lésion, Rev. neurol. 26:647, 1913.
28. Milch, Henry, and Green, H. H.: Calcification about the flexor carpi ulnaris tendon, Arch. Surg. 36:660, 1938.
29. Moersch, F. P.: Median thenar neuritis, Proc. Staff Meet., Mayo Clin. 13:220, 1938.
30. Nissen, K. I.: Etiology of carpal compression of median nerve, J. Bone & Joint Surg. 34B:514, 1952.
31. Paget, James: Lectures on Surgical Pathology, Delivered at the Royal College of Surgeons of England, ed. 3, p. 50, Philadelphia, Lindsay & Blakiston, 1865.
32. Parsons, F. G., and Robinson, Arthur: Eighth report of the Committee of Collective Investigation of the Anatomical Society of Great Britain and Ireland for the year 1897-1898, J. Anat. & Physiol. 33:189, 1898.
33. Phalen, G S.: Spontaneous compression of the median nerve at the wrist, J.A.M.A. 145:1128, 1951.
34. Phalen, G. S., Gardner, W. J., and La Londe, A. A.: Neuropathy of the median nerve due to compression beneath the transverse carpal ligament, J. Bone & Joint Surg. 32A:109, 1950
35. Phalen, G. S., and Kendrick, J. I.: Compression neuropathy of the median nerve in the carpal canal, J.A.M.A. 164:524, 1957.
36. Pimm, L. H., and Waugh, W.: Tuberculous tenosynovitis, J. Bone & Joint Surg. 39B:91, 1957.
37. de Quervain, F.: Ueber eine Form von chronischer Tendovaginitis, Cor.-Bl. f. schweiz. Aerzte 25:389, 1895.
38. Sherry, J. B., and Anderson, W.: The natural history of pigmented villonodular synovitis of tendon sheaths, J. Bone & Joint Surg. 37A:1005, 1955.
39. Sprecher, E. E.: Trigger thumb in infants, J. Bone & Joint Surg. 31A:672, 1949.
40. Stein, A. H., Jr., Ramsay, R. H., and Key, J. A.: Stenosing tendovaginitis at radial styloid process (de Quervain's disease), A.M.A. Arch. Surg. 63:216, 1951.
41. Vasko, J. R.: Calcareous tendinitis of flexor tendon of finger: report of case, J. Bone & Joint Surg. 28:638, 1946.
42. Wagenseil, F.: Quoted by Loomis, L. K.[25]
43. Walker, O. R., and Hall, R. H.: Coccidioidal tenosynovitis: report of a case, J. Bone & Joint Surg 36A:391, 1954.
44. Ward, L. E., Bickel, W. H., and Corbin, K. B.: Median neuritis (carpal tunnel syndrome) caused by gouty tophi, J.A M.A. 167:844, 1958.
45. White, J. W., and Jensen, W. E.: Trigger thumb in infants, A.M.A. Am. J. Dis. Child. 85:141, 1953.
46. Woltman, H. W.: Neuritis associated with acromegaly, Arch. Neurol. & Psychiat. 45: 680, 1941.
47. Wood, John: Variations in human myology observed during the winter session of 1867-68 at King's College, London, Proc. Roy. Soc., London 16:483, 1868.
48. Zachary, R. B.: Thenar palsy due to compression of median nerve in carpal tunnel, Surg., Gynec. & Obst. 81:213, 1945.
49. Zadek, I.: Stenosing tendovaginitis of thumb in infants, J. Bone & Joint Surg 24:326, 1942.

Tenosynovitis de Mano e Carpo
Syndrome del Tunnel Carpal, Morbo de de Quervain, Digito a Resorto

Summario in Interlingua

Es signalate le frequente occurrentia del syndrome del tunnel carpal, del morbo de de Quervain, e del digito a resorto como resultato de tenosynovitis. In omne le tres conditiones, feminas es afficite plus frequentemente que homines, e omne le tres

conditiones se vide le plus communmente in patientes in le quinte e le sexte decennio del vita. Le mano o carpo dextere es interessate plus frequentemente que le sinistre. Ben que il es probabile que factores occupational ha un rolo in le production del tenosynovitis e del symptomas de omne le tres syndromes, altere factores o morbos relationate a arthritis rheumatoide es etiam importante. Restablimento spontanee es possibile, e il etiam occurre que le tres conditiones responde al injection de hydrocortisona in le vainas synovial. In multe casos, le tractamento le plus conservatorie consiste in le relaxation chirurgic del constringite tendines o nervos. Es importante usar incisiones alineate con le plica thenar in casos del syndrome del tunnel carpal, incisiones transverse al radial processo styloide in casos de stenosante tenosynovitis de de Quervain, e incisiones transverse alineate con le plicas al base del pollice e in le palma in casos de stenosante tenosynovitis del vainas flexori del digitos. Altere elementos de importantia pro le successo del tractamento es le uso de hydrocortisona circa le tendines al tempore del operation, biopsia del synovia in omne casos, suturation de solmente le pelle, e application de un apparato de supporto durante alicun dies usque le reaction al effecto del operation has subsidite, sequite per le prompte remobilisation de carpo e mano.

15

The Prevention and the Correction of Adduction Contracture of the Thumb

J. William Littler, M.D.*

An adduction-flexion deformity of the thumb involving the carpometacarpophalangeal joints constitutes one of the most disabling structural derangements seen in reconstructive hand surgery. The deformity is characteristic: the normal great cleft separating the thumb and the fingers is reduced in varying degrees, depending upon the nature and the severity of the lesion; in advanced states, the thumb is rotated externally, bound firmly to the second metacarpal, and lies in a plane with the fingers. The basis of this chapter is the writer's numerous encounters with the problem during and since World War II.

The thumb's unique functional status is vulnerable because of the unusual mobility of its basal saddlelike articulation, complex intrinsic musculature responsible for stability and a relaxed cutaneous web. In the fourth *Bridgewater Treatise*, Sir Charles Bell wrote:

> On the length, strength, free lateral motion and perfect mobility of the thumb, depends the power of the human hand. The thumb is called *pollex* because of its strength, and that strength is necessary to the power of the hand, being equal to that of all the fingers.

In descriptive Greek terminology the thumb is the *anticheir,* being independent of and diametric to the other digits of the hand.

Although an opposable thumb greatly empowers grasp, its major significance is related to the refinement of pinch Power is provided by the great mechanical advantage of the ulnar innervated adductor-flexor intrinsic musculature acting on the proximal phalanx, especially the transverse fibers of the adductor pollicis. In the presence of an ulnar motor paralysis, the thumb is weakened woefully at the metacarpophalangeal joint and assumes a characteristic hyperextension or recurvatum deformity (break in the longitudinal arch) when an attempt is made to pinch. The weakened pinch is known as Froment's sign.

The ability to circumduct or oppose the thumb is a basic functional attribute of the hand. However, without the power of adduction, grasp is subserved but not pinch Abducting and opposing musculature, innervated by the median nerve, serves to position and stabilize the thumb metacarpal, thereby allowing the full force of the adductor and the short flexors to be directed against the object in grasp or pinch. Effective power is the resultant of the forces of thumb opposition and adduction working against a relatively fixed finger unit group. Like the radius, of which it appears morphologically to be a part, pronation is a most important characteristic of the thumb.

In that the basic function of the thumb is to oppose the fingers, fixed adduction renders it ineffective for this purpose and destroys the essential elements of grasp and pinch. Because of the frequent and disabling consequence, this deformity warrants special attention with reference to the productive factors, prevention and surgical correction.

* New York, N Y

Of the following, any one, or combination, may be active in the development of the problem.

FAULTY IMMOBILIZATION

The functional range or position of the first metacarpal may be seriously impaired by careless and prolonged splinting. A tight dressing or plaster, binding the first metacarpal to the second, can render the thumb useless through secondary stiffening of the carpometacarpal joint and contracture of the cutaneous web, fascia and interosseous musculature. This strangulation of the hand and the forearm produces digital edema, pain, pressure necrosis of skin, ischemia of muscles, reflex dystrophy, ultimate fibrosis and a fixed contracture (Fig. 1). Whenever possible, immobilization of the thumb should be in radiopalmar abduction. This functional position has been emphasized repeatedly, but often it is neglected in the management of hand and upper-extremity injuries. Optimum position affords the greatest general use despite the possibility of limited movement; it is of especial importance when the thumb must be fused to correct a deformity or to overcome pain. The thumb metacarpal assumes its prime position when a tight fist is made, and it is in this position that the first metacarpal should be fused to the carpus, thereby establishing a functional relationship with the fixed carpal arch and the second metacarpal unit (Fig. 2).

Not since Kanaval coined the phrase *position of function* have so few words meant so much to the mechanics of recovery in the injured hand. However, it is appalling that so many otherwise useful hands still are left crippled through the neglect of such a simple factor as positioning. It is impossible to maintain ideal thumb-and-finger relationships in all cases, especially when gross destruction is present, but paramount is the need to achieve a useful position through basic primary and secondary care. In the primary phase, vigilance is essential if the hand is not to be jeopardized by a constricting dressing or plaster, poor thumb position and general circulatory impairment.

In *Madame Bovary*, Flaubert draws the classic picture of the tight appliance. Charles Bovary's Achilles' tenotomy on the clubfoot of the stable boy Hippolyte after the manner

Fig. 1. Severe adduction-flexion contracture of thumb secondary to compression ischemia. Constriction of the hand by a tight plaster used to immobilize a simple fracture of the humerus resulted in soft-tissue necrosis and intrinsic muscle fibrosis.

15

The Prevention and the Correction of Adduction Contracture of the Thumb

J. WILLIAM LITTLER, M.D.*

An adduction-flexion deformity of the thumb involving the carpometacarpophalangeal joints constitutes one of the most disabling structural derangements seen in reconstructive hand surgery. The deformity is characteristic: the normal great cleft separating the thumb and the fingers is reduced in varying degrees, depending upon the nature and the severity of the lesion; in advanced states, the thumb is rotated externally, bound firmly to the second metacarpal, and lies in a plane with the fingers. The basis of this chapter is the writer's numerous encounters with the problem during and since World War II.

The thumb's unique functional status is vulnerable because of the unusual mobility of its basal saddlelike articulation, complex intrinsic musculature responsible for stability and a relaxed cutaneous web. In the fourth *Bridgewater Treatise*, Sir Charles Bell wrote:

> On the length, strength, free lateral motion and perfect mobility of the thumb, depends the power of the human hand. The thumb is called *pollex* because of its strength; and that strength is necessary to the power of the hand, being equal to that of all the fingers.

In descriptive Greek terminology the thumb is the *anticheir,* being independent of and diametric to the other digits of the hand.

Although an opposable thumb greatly empowers grasp, its major significance is related to the refinement of pinch. Power is provided by the great mechanical advantage of the ulnar innervated adductor-flexor intrinsic musculature acting on the proximal phalanx, especially the transverse fibers of the adductor pollicis. In the presence of an ulnar motor paralysis, the thumb is weakened woefully at the metacarpophalangeal joint and assumes a characteristic hyperextension or recurvatum deformity (break in the longitudinal arch) when an attempt is made to pinch. The weakened pinch is known as Froment's sign.

The ability to circumduct or oppose the thumb is a basic functional attribute of the hand. However, without the power of adduction, grasp is subserved but not pinch. Abducting and opposing musculature, innervated by the median nerve, serves to position and stabilize the thumb metacarpal, thereby allowing the full force of the adductor and the short flexors to be directed against the object in grasp or pinch. Effective power is the resultant of the forces of thumb opposition and adduction working against a relatively fixed finger unit group. Like the radius, of which it appears morphologically to be a part, pronation is a most important characteristic of the thumb.

In that the basic function of the thumb is to oppose the fingers, fixed adduction renders it ineffective for this purpose and destroys the essential elements of grasp and pinch. Because of the frequent and disabling consequence, this deformity warrants special attention with reference to the productive factors, prevention and surgical correction.

* New York, N. Y

Of the following, any one, or combination, may be active in the development of the problem.

FAULTY IMMOBILIZATION

The functional range or position of the first metacarpal may be seriously impaired by careless and prolonged splinting. A tight dressing or plaster, binding the first metacarpal to the second, can render the thumb useless through secondary stiffening of the carpometacarpal joint and contracture of the cutaneous web, fascia and interosseous musculature. This strangulation of the hand and the forearm produces digital edema, pain, pressure necrosis of skin, ischemia of muscles, reflex dystrophy, ultimate fibrosis and a fixed contracture (Fig. 1). Whenever possible, immobilization of the thumb should be in radiopalmar abduction. This functional position has been emphasized repeatedly, but often it is neglected in the management of hand and upper-extremity injuries. Optimum position affords the greatest general use despite the possibility of limited movement; it is of especial importance when the thumb must be fused to correct a deformity or to overcome pain. The thumb metacarpal assumes its prime position when a tight fist is made, and it is in this position that the first metacarpal should be fused to the carpus, thereby establishing a functional relationship with the fixed carpal arch and the second metacarpal unit (Fig. 2).

Not since Kanaval coined the phrase *position of function* have so few words meant so much to the mechanics of recovery in the injured hand. However, it is appalling that so many otherwise useful hands still are left crippled through the neglect of such a simple factor as positioning. It is impossible to maintain ideal thumb-and-finger relationships in all cases, especially when gross destruction is present, but paramount is the need to achieve a useful position through basic primary and secondary care. In the primary phase, vigilance is essential if the hand is not to be jeopardized by a constricting dressing or plaster, poor thumb position and general circulatory impairment.

In *Madame Bovary*, Flaubert draws the classic picture of the tight appliance. Charles Bovary's Achilles' tenotomy on the clubfoot of the stable boy Hippolyte after the manner

FIG. 1. Severe adduction-flexion contracture of thumb secondary to compression ischemia. Constriction of the hand by a tight plaster used to immobilize a simple fracture of the humerus resulted in soft-tissue necrosis and intrinsic muscle fibrosis.

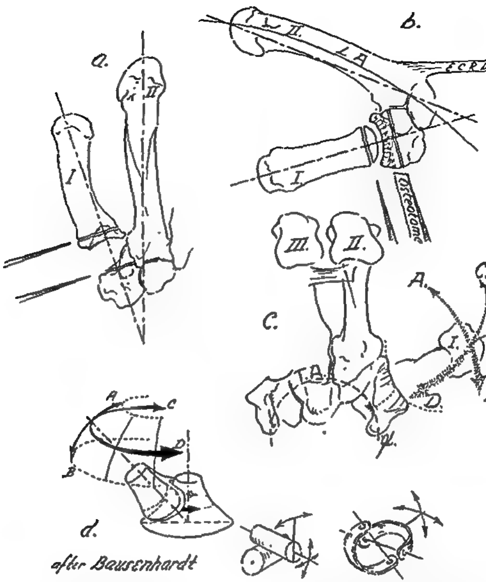


FIG. 2. (a) dorsal and (b) lateral Mean projection of first metacarpal from articular surface of greater multangular results in optimal position with reference to fixed carpo second and third metacarpal unit (See roentgenogram [Fig. 5, *bottom*] with metacarpal fused to carpus in functional position.)

(c) First metacarpal positions: A—palmar adduction (ulnar n); B—palmar abduction (median n.); C—extension abduction (radial n); D—flexion adduction (ulnar n); and E—rotation (I. supination [E.P.L., Add , 1st D.I.]. II pronation [opponens P., Abd. P. Br.]).

Rotation permitted by imperfect articulation between greater multangular and metacarpal, the articular radius of the metacarpal being less than that of the greater multangular in the transverse axis and greater in the vertical. In full pronation the lateral articular surfaces are locked

(d) Geometric representation of first carpometacarpal joint showing rotative characteristics and simple functional mechanical examples. Except for axial rotation, the action of an airplane aileron and elevator control stick has much in common with the first metacarpal. The joint is essentially a ball-and-socket unit, with one axis reversed, but retaining the same universal movement.

L.A —longitudinal carpometacarpal arch. T.A.—transverse carpal arch E C R.L and Br.—radial wrist extensors The E C.R. Br. is the prime one, inserting at the apex of the carpal arch.

(After Bausenhardt: Ztschr. Anat. 114:253)

of Delpech was turned to disaster as the foot and the leg were strangulated by external mechanical fixation:

With many precautions to avoid altering the position of the limb, the box was then removed and a frightful spectacle exposed. The shape of the foot was indistinguishable in such a swelling that the entire surface of the skin seemed about to rupture, and it was covered with bruises caused by the famous appliance. Hippolyte had already complained of pain from it; they had paid no attention; they were now forced to admit that he had not been completely mistaken and they left him free for a few hours. But scarcely had the pain of the oedema subsided when the two learned men judged it time to restore the limb to the appliance, squeezing it even more tightly to hasten matters. Then, three days later, Hippolyte being unable to endure it any longer, they removed the apparatus once more, being vastly astonished by the results they discovered. A livid tumefaction extended down the leg, with blisters here and there from which oozed a black exudate.

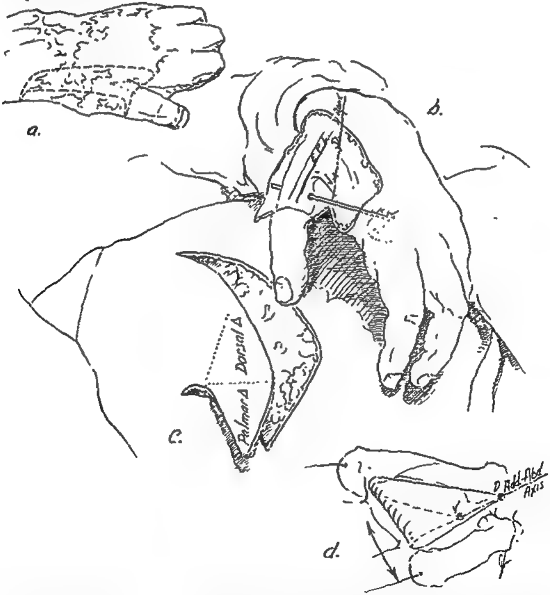


Fig. 3. Principles of first intermetacarpal resurfacing. (a) Incision to liberate first metacarpal. (b) In *burns*, resection of cicatrized skin generally permits freedom of first metacarpal with preservation of interosseous intrinsic musculature. Metacarpal abduction maintained with Kirschner wire during pedicle-healing phase. (c) Right or left upper abdominal *pedicle design*—flap carried over dorsoradial aspect of thumb metacarpal with *dorsal (D)* and palmar (V) triangular apices at the adduction-abduction axis (d). Detachment following 3 weeks of immobilization.

And many a forearm and hand have suffered such a history.

INADEQUATE SKIN

Cicatricial skin contractures of the thumb web secondary to burns and other trauma are a common cause of the adduction deformity. Mangle burns also crush the hand, rupture the volar ligament and flatten the carpal arch, and often destroy the thenar musculature. In these circumstances the thumb is rotated externally into a plane with the fingers, and the transverse carpal and metacarpal arches are fixed in reverse by a heavy plaque of dorsal scar; an extensive surgical intervention is required to restore the basis architecture and supply relaxed integument through pedicle and free skingrafting in these cases (Fig. 3). Loss of coverage over the first intermetacarpal space without adequate skin replacement or healing by secondary epithelization leads invariably to some degree of adduction contracture. The normally mobile first metacarpal is affected especially by any reduction in the pliability of dorsal skin and web. With the hand flat and the thumb adducted, the skin distance from the ulnar to the radial aspect of the hand is approximately 5 inches in the adult; however, when a fist is made, the skin distance is expanded to over 6 inches. This dorsal transverse skin excess or relaxation is essential for full thumb abduction, just as it is for full finger flexion at the metacarpophalangeal joints. Primary edema and secondary subcutaneous dorsal cicatrix checkrein the transverse and the longitudinal arches of the hand by adducting the thumb and hyperextending the fingers at the metacarpophalangeal joints. Whereas 1 inch of transverse dorsal skin relaxation is necessary for the full development of the transverse arch of the hand, approximately 2 inches is required longitudinally for the wrist and the fingers when these are fully flexed.

If, in the presence of a narrowed first interosseous space, skin replacement is inadequate, or if a pedicle flap or a free [illegible] placed so that its distal margin bridges the first and the second metacarpal heads, contracture of the suture line will tether the first metacarpal, and mobility will be reduced despite good abduction gained at the time of operation. The flap or the graft must be carried into the palm as a triangular projection to a point approaching the abduction axis of the first metacarpal (Fig. 3d). Congenital webbing of the thumb and the index finger generally requires a deepening of the cleft through local flaps and free skin grafts. A Kirschner-wire skeletal abduction splint may be necessary to maintain the separation during the healing phase.

DUPUYTREN'S CONTRACTURE

In a small percentage of cases varying degrees of palmar fascial hypertrophy and contracture will limit thumb abduction. The fascial band involved is readily demonstrated spanning the palmar aspect of the thenar web. A subcutaneous fasciotomy may be effective in releasing the thumb from its restraint, but a far more satisfactory and permanent result is gained through an excision of the involved fascia and a Z-plasty.

ISCHEMIA OF INTRINSIC MUSCULATURE

Major arterial interruption secondary to crush and lacerating wounds of the arm and the forearm can produce an ischemic fibrosis of the intrinsic adducting muscles of the thumb; dressings or plaster encompassing the hand and the forearm must be applied with extreme care, for compression compounds the oligemic state. Skin generally will survive despite diminished circulation if it is not subjected to pressure.

Careful maintenance of the thumb in abduction may overcome the more critical potential of an intrinsic muscle contracture, but if, ultimately, a severe fixed contracture is established, an exc[illegible] of the fibrosed interosseous mus[illegible] [illegible]ough a dorsal incision [illegible] metacarpal often will liberate [illegible] skin replace-

FIG. 4. (*Top, left*) Adduction-flexion contracture of right thumb secondary to ischemic necrosis and fibrosis of interosseous intrinsic musculature. (Positions A and D, Fig. 2.) Radial and ulnar arteries divided at wrist. (*Top, right*) Resection of fibrotic musculature (first dorsal interosseous, adductor and short flexors) through parametacarpal incision; thumb abduction maintained by special Kirschner-wire skeletal distraction splint. (*Bottom*) Roentgenogram showing Kirschner-wire splint in place. The distraction can be made either through the thumb and the index proximal phalanges or the metacarpals, depending upon the degree of metacarpophalangeal involvement.

ment (Fig. 4). The muscles will be fibrosed and their core reduced to masses of yellow necrotic tissue. Total resection of the first dorsal interosseous, the adductor and the mesial and the lateral short flexors from their origin deep in the apex of the interosseous space is essential in order to liberate the metacarpal and proximal phalanx. Care should be taken to preserve the deep arterial arch and princeps pollicis artery. Generally, compensation for intrinsic muscle loss is possible through a sublimis tendon transfer for either adduction or opposition, or both. Opposition is first restored to the mobilized thumb.

NERVE LESION

Paralysis of the opposing median innervated intrinsic thenar muscles may cause the thumb to lie flat against the side of the hand actively adducted and rotated externally by the extensor pollicis longus. The long thumb extensor is antagonistic to opposition, and, when the thumb remains in this nonfunctional position, an adduction contracture may develop if care is not taken to maintain a full passive range of palmar abduction until active opposition has been restored through intrinsic muscle reinnervation or tendon transfer. Some compensation for thumb opposition in median nerve paralysis is seen not infrequently through ulnar innervation of the lateral flexor pollicis brevis.

A wrist drop resulting from a radial nerve paralysis can produce an adduction deformity of the thumb if the inactive long thumb extensor becomes adherent within its fibro-osseous canal at the wrist. Further impairment results from the paralyzed abductor pollicis longus, which allows the metacarpal to be adducted into the palm. The spastic hand will not be discussed.

LOCAL INJURY

Destruction of soft tissue, first and second metacarpal fractures, hemorrhage and involvement of the first carpometacarpal joint

will impair greatly the functional mobility of the thumb and reduce the intermetacarpal cleft, especially if adequate primary soft-tissue closure and reduction of fractures have not been achieved. A crush injury of the hand can flatten the carpal arch through a rupture of the transverse volar ligament and a fracture dislocation laterally of the greater multangular; the thumb thereby is rotated externally so that its metacarpal lies in a plane with those of the fingers, and the mechanics of opposition are destroyed. Generally, a resection of the carpometacarpal joint and a fusion of the metacarpal to the carpus in a functional position are necessary

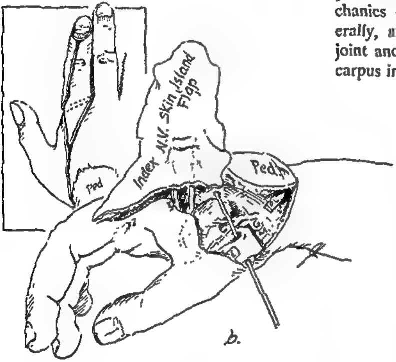


FIG. 5. (*From top to bottom*): (1) Crush injury of right hand with thenar muscle paralysis and a fibrotic adduction contracture of the thumb. (2) Skin fillet and amputation of relatively functionless index finger. Resection and fusion of first carpometacarpal joint in functional position. Radiodorsal skin deficit to be closed by index neurovascular skin island pedicle flap. (3) Index skin island closure and fused functional position of thumb. (4) Kirschner-wire fixation of first carpometacarpal joint resection

for the restoration of thumb-and-finger function (Fig. 5). Explosive wounds of the hand are a common cause of thumb web and articular disruption.

INFECTION

The wake of cicatrix following a primary or a secondary infectious process of the first interosseous space will bind in varying de-

FIGS. 6 to 8, same case. Fig. 6. Severe adduction contracture of right thumb secondary to extensive infection originating in the metacarpophalangeal joint of the index finger.

FIG. 7. Preoperative roentgenogram.

FIG 8. Postoperative roentgenogram showing resection of index ray. Corrective osteotomy of first metacarpal base. Radiodorsal aspect of hand resurfaced with neurovascular pedicle skin flap from index, as shown in Figure 5, *bottom, left*.

grees the thumb metacarpal to the side of the hand. An extensive surgical procedure may be necessary to liberate the metacarpal and reconstruct the web (Figs. 6-8).

Correction of the adduction deformity falls into one or more of several categories depending on the nature of the involvement but, specifically, whether or not additional skin and subcutaneous tissue must be provided. If not too severe, a thumb adducted through malpositioning, paralysis of opposing musculature or disuse, can be mobilized

FIG. 9. (*Top*) Thumb web contracture secondary to burn and contracted free skin graft. (*Bottom*) Correction of web contracture through interdigital local skin flaps.

by active abduction traction splinting alone if started early; however, most cases of long standing require surgical intervention.

A simple border contracture of the web is released by a Z-plasty (Fig. 9). When the skin alone is involved, as in burns, replacement of the cicatrized web by a thick split graft secured by a stent dressing may overcome the deformity. The graft is carried from the dorsal to the volar apex of the wedge created by the abducted first and second metacarpals; however, the cavitation and the irregularity of the first intermetacarpal space following excision of scar and fibrosed interosseous musculature often make difficult, if not impossible, the satisfactory application

FIG. 10. Intermetacarpal abdominal pedicle flap *in situ*. Metacarpal abduction maintained by Kirschner-wire skeletal splint.

FIG. 11. (*Top*) Moderate cicatricial adduction contracture volar aspect of right thumb showing abduction loss. A measurement from the ulnar aspect of the hand at the metacarpophalangeal level to the pulp of the thumb will give a comparative figure with respect to the normal. (*Bottom*) Full abduction gained through scar excision and abdominal pedicle coverage. A triangle of the flap is projected dorsally to eliminate a transverse scar.

of a free skin graft; so that, whenever skin and deep structures are involved, pedicle skin is required for web reconstruction. During the period of resurfacing, the thumb is held in full abduction by skeletal Kirschner-wire fixation (Fig. 10). A folded diamond pattern forming a dorsal and a palmar triangle fills and resurfaces the cleft, and eliminates an undesirable suture line between the first and the second metacarpal heads. The interosseous defect is handled most easily by an abdominal pedicle flap with its base superior. The flap is carried over the dorsoradial aspect of the thumb metacarpal (Fig. 3).

In some severe cases of adduction contracture, the index finger is damaged to a degree requiring amputation. By sectioning and removing the second metacarpal at its base, a good opening is gained between the thumb and the middle finger. The skin of the amputated digit can be used as a local neurovascular island pedicle graft to resurface any interosseous defect, thus eliminating the need for an abdominal pedicle flap. In most cases of adduction contracture, the interosseous musculature and fascia must be excised to mobilize the first metacarpal when the pedicle flap is set in. Palpation of the musculature with the metacarpal abducted will indicate the fibrosed elements requiring excision.

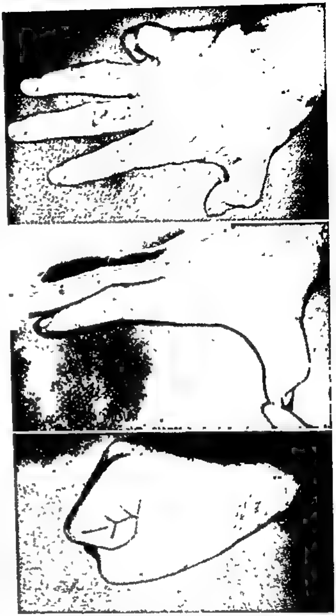


FIG. 12. (*Top*) Third-degree burn; dorsum of right hand incompletely resurfaced and heavily cicatrized through secondary healing. The little finger is deformed and functionless, the metacarpophalangeal joints are check-reined in extension by the dorsal scar, and the thumb is tightly adducted. (*Center*) The little finger has been amputated; the dorsum resurfaced with a free skin graft and the thumb and the web with a pedicle flap. Full thumb abduction restored. (*Bottom*) Lateral view showing full metacarpophalangeal flexion and thumb pronation.

If the dorsal skin of the first interosseous space web is relatively relaxed or uninvolved despite fixed adduction of the first metacarpal secondary to an ischemic contracture, generally excision of the fibrosed interosseous muscles and fascia, together with a skeletal Kirschner-wire distraction splint, will permit mobilization of the thumb (Fig. 4). Loss of opposition or adduction, or both, can be restored through appropriate tendon transfers. In the restoration of opposition, external dynamic traction splinting should be maintained until the transferred tendon has gained enough power to hold the thumb in the functional position. As stated above, a tendon transfer for opposition takes precedence over one for adduction.

Position and stability are essential to useful function, and the thumb should be fixed, despite mobility, if there is an intrinsic muscle deficiency, or if there is insufficient motor power for compensatory tendon transfer.

When the thumb must be stabilized, either an intermetacarpal bone strut or a fusion of the carpometacarpal joint should be considered. Fixation of the thumb demands great care to ensure a useful position. For practical purposes, the thumb must be so placed that the index and the middle fingers will converge against its pulp. In general, arthrodesis of the thumb metacarpal should be a last resort, but, when the adducting and abducting intrinsic muscle function cannot be preserved or restored, a fusion is mandatory.

Le Prevention e Correction de Contractura Adductional del Pollice

Summario in Interlingua

Le independentia, fortia, e mobilitate, que es indispensabile in le pollice in actos del sasir e del pincear, es compromittite plus o minus seriemente per le presentia de contractura adductional. Iste deformitate es un del plus frequente e del plus invalidante conditiones manual. Plure factores—a parte un affection primari del prime spatio intermetacarpal — es responsabile pro illo. Le plus importante tal factor es le positionar incorrecte durante prolongate periodos de immobilisation. Si le prime osso metacarpal es ligate solidemente contra le latere del mano, le histos molle del prime spatio interossee es comprimite e un grado sever de contractura pote resultar. Edema e insufficientia del provision de sanguine pote resultar in un fibrose del intrinsec musculatura adductori del pollice a un tal grado que le function del pollice es eliminate plus o minus completemente. Cicatrisation—occurrente secundari o arditura o altere formas de trauma que affice le dorso del mano—pote adducer le pollice e reducer le transverse arco metacarpal a tal grados que le opponibilitate de pollice e digitos es perdite totalmente. Etiam infection e le trauma directe del region del prime spatio intermetacarpal pote resultar in le adduction e immobilisation del pollice. Le paralyse del intrinsec musculatura oppenitori permitte al pollice jacer in le position adducite, e si illo non es supportate per un apparato dynamic e per exercitios passive, un contractura pote disveloppar se. Le deformitate que resulta ab iste varie factores pote, in multe casos, esser corrigite per un apparato de abduction o per manovras chirurgic que visa a disligar le pollice e a restaurar, si necessari, su stato functional per recopertura a pelle pediculate, per arthrodesis, e per transferimento de tendine.

16

Interphalangeal Joint Stiffness

RICHARD C. MILLER, M.D.*

Lack of motion of some components of the hand always has been and will remain the principal difficulty encountered in care of the injured hand. This lack of mobility can occur through a reduction in the gliding capacity of tendons, restriction in mobility or amount of soft tissue, or limitation of range of the normal motion of a joint from tissues intrinsic to the joint. The interphalangeal joints and the metacarpal joints frequently are the site of reduced mobility. A pessimistic attitude has developed toward the task of alleviation of interphalangeal joint stiffness that is not reflected toward alleviation of tendinous or soft-tissue sources of restriction of motion, and is much less pronounced in regard to stiffness arising in the metacarpal phalangeal joint. Doubtless there is a certain justification for this attitude, but the author feels that attention could properly be directed to this problem in hopes of finding some sources of benefit for the disabled hand. Rather than state categorically, as often is done, that arthrodesis or amputation is the only alternative to a protruding finger if this protrusion arises in an interphalangeal joint that will not respond to the usual treatment, we are in need of other methods of correction.

Most satisfactory treatment has been physical therapy with passive forcing, heat in its various forms, and numerous unguents applied with various propelling physical modalities. In addition, the use of dynamic splinting with the "knuckle bender" of Bunnell[2] and the traction glove has been of value in a large number of cases. Intermittently most of us have tried forcible manipulation of stiff joints under the influence of anesthesia, and I believe it can be said safely that the majority have abandoned the procedure immediately, in that stiffness frequently was more severe after manipulation than before it.[6] With the failure of these three principal types of conservative therapy, usually the failure of only two—that is, physical therapy and dynamic splinting—it has been felt that the patient either accepted the disability or the alternative of arthodesis in a better position or amputation. However, more and more, articles indicate a concern with increasing the motion of the joints, a most striking example being the recent report of Brannon and Klein[1] of the introduction of a metallic hinge prosthesis as a substitute for the badly deranged joint.

Several anatomic considerations involving the interphalangeal joints are of importance in weighing surgery.[5] In the distal interphalangeal joint, the extensor apparatus becomes an intimate part of the reinforcement of the dorsal capsule of the joint. On the volar aspect of this joint, whereas immediately overlying the articular surface there is free gliding of the profundus tendon, just distal to the joint the tendon becomes adherent to the palmar plate of the volar capsule and also inserts into the periosteum of the distal phalanx. In the proximal interphalangeal joint, there is no attachment of the flexor tendons; however, there is intimate attach-

* Spokane, Wash.

ment of the central portion of the extensor communis tendon to the dorsum of the joint capsule acting as a reinforcing ligament. The collateral ligaments are distinctive structures that are considerably more taut in their normal application than the collateral ligaments of the metacarpal phalangeal joints, as is evidenced by the increased stability of the interphalangeal joints to lateral motions, also easily demonstrated simply by pulling on the finger and finding that all the give is at the proximal joint. The stability of the joint, insofar as lateral motion is concerned, comes not only from the tautness of the ligaments but also from the bicondylar configuration and width of the articulating surfaces. Little lateral stability is afforded the middle joints, and none is given the distal joints by lateral intrinsic tendons that do stabilize laterally the proximal joints. Thus, from this brief résumé it is seen that injury to an interphalangeal joint almost presupposes injury

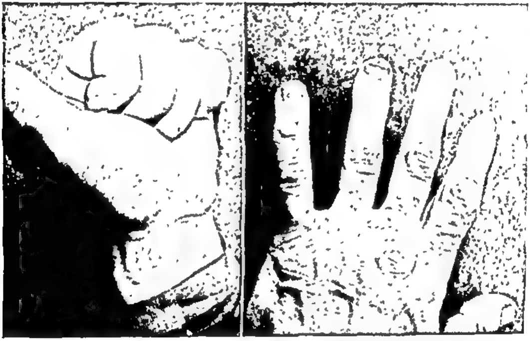


FIG. 1 Arthroplasty and repair of extensor tendon of ring finger, distal joint. Patient is a violinmaker and needed motion for testing; therefore, arthrodesis would not be satisfactory. Flexion and extension 70°.

FIG 2. Result of capsulectomy of middle joint of ring finger 18 months after operation. No loss of intrinsic muscle action, as shown in extension at *left*.

of some type to a surrounding tendon. This is one of the principal factors limiting the obtaining of satisfactory results by a surgical procedure on these joints.

There are increasing reports of benefit by operative procedures. Arthroplasty has been carried out satisfactorily in a reasonably large series of cases by Carroll[7] with results that certainly justify its use. Unfortunately, its application is limited by the necessity, as given in the criteria for choice of patients, of normal tendons surrounding the joint, which prerequisite by anatomic considerations limits the application of the procedures. Another limitation that narrows applicability but increases the probability of a satisfactory arthroplasty is that one articular surface must be largely intact. When one articular surface is intact, some tendon restoration can be done as well as arthroplasty. (Fig. 1)

Another procedure that is satisfactory in the proximal joint in limited circumstances is capsulectomy. By and large in the literature it is discarded as unsatisfactory in the middle or the distal joints. Under the strict criteria of (1) normal articular surfaces to x-ray, (2) normal tendons and (3) a stiff joint that has not responded to more conservative means, capsulectomy of the proximal interphalangeal joint in four instances has produced a range of motion from 70° to 90° that has been maintained. (Fig. 2) Almost invariably, the circumstances leading to such a procedure are fracture in proximity to the joint, frequently extending into the articular area. The feared lateral instability quoted frequently as a deterrent has not occurred in the small series. It has been impossible, when the intrinsic tendons were carefully elevated and preserved, to excise enough of the ligaments to produce such instability. Indeed, with the relatively broad configuration of the joint and the bicondylar shape, if the dorsal and the volar ligaments of the joint are intact, lateral instability will be minimal. Probably the instability seen with traumatic tear of the ligaments is accompanied by injury to the volar and the dorsal ligaments, thus allowing the increased motion. The procedure has been carried out almost identically with the familiar capsulectomy of the proximal joint,[7] the incisions being lateral on both sides of the joint, with elevation of the intrinsic tendon, which is partly attached on its more volar aspect, and then excision of the collateral ligaments. Almost always these are hypertrophied markedly in the cases chosen, being up to 3/16 of an inch in thickness in the cases seen by this writer. As soon as the ligaments are excised, flexion of the joint is possible immediately without great pressure. The use of immobilization in flexion, as is done with proximal joint capsulectomy, has not been necessary. If mobility cannot be maintained by the patient or physical therapy undertaken, then the use of a dynamic flexion splint is indicated.

Another procedure that carries a limited applicability but perhaps has been used too conservatively is that of joint transplantation. This procedure could be regarded as an alternative to the metal hinge prothesis. As compared with the metallic joint, it would have the marked disadvantage of requiring a donor site, either another finger or a toe, and also limitation in the range of size of available joints. As to hypothetic advantages, these are: (1) The use of material that becomes an integral part of the body ultimately and on possible secondary injury would have no tendency to extrusion or other difficulties that might arise from even the most inert of foreign materials; and (2) the difficulty to conceive of a permanent insertion of a tendon to metal wherein, by joint transfer, it is possible to transfer the tendon attachment with the bony structure.

CASE REPORT

R. J. B., seen January 5, 1957, 6 weeks after injury in which the right hand was lacerated severely by a circular saw. The patient suffered a near-complete traumatic amputation of the middle finger from the volar aspect through the base of the proximal phalanx, only the dorsal skin being left. The saw had extended distally across the ulnar side and the dorsum of the index fin-

FIG 3. Roentgenogram showing nonunion of middle finger. (*Top*) 60° ulnar angulation of middle joint of this index finger with disruption of both joint surfaces. (*Center*) 45° flexion of transplanted joint. (*Bottom*) Extended. Note the reasonably normal alignment of the index finger. Not shown in this view is some dropping of the distal joint.

ger, avulsing tissue, including a good deal of the middle joint of the index finger. Suture of the severed flexor tendons of the middle finger had been done, as well as an attempt on the extensor tendon of the index finger. Due to inadequate vascularity, there were several areas of necrosis, and when first seen he had granulating areas on the volar aspects of the middle finger and on the dorsum overlying the middle joint of the index finger, with some purulent drainage.

By February 15 there was complete healing with no further drainage. There was no flexor or extensor action, nor sensation in the middle finger, with a flexion contracture of 60° of the middle and the distal joints, and nonunion of the fracture with some sclerosis of the bone (Fig. 3, *top*). On the index finger there was 60° of ulnar deviation at the middle joint. However, there was definite flexor tendon action at the distal joint, indicating an intact profundus tendon, although there was no flexion at the middle joint because of joint disturbance. Extension of the middle joint was not measurable because of inability to flex actively or passively. Extension was possible at the distal and the proximal joints.

On April 5, 1957, operative procedure was carried out with amputation of the middle finger through the nonunion fracture, the dorsal skin being preserved. From the specimen, a subperiosteal resection was done of the remaining proximal phalanx and the proximal portion of the middle phalanx, preserving carefully the extensor tendon central slip and its attachment to the base of the middle phalanx. Thus, resection was carried out on the entire middle joint without its ligaments. All the extensor tendon in the amputated segment was left attached to the middle phalanx. The joint of the index finger then was exposed subperiosteally through the scarred ulnar portion. The pointed area of the proximal phalanx was resected, and a resection was carried out also on the base of the middle phalanx. The joint that had been resected from the middle finger next was inserted into the subperiosteal space remaining. Extreme care was taken so that at no time was the flexor tunnel entered. Fixation of bony fragments was by drilling and the use of chromic gut. At this stage preoperative evaluation proved to be wrong; there was inadequate soft tissue to close the wound in the

index finger due to discrepancy in size of the newly inserted joint with the removed bone. Because of this, the remaining attached dorsum of the middle finger was tubed and used as a replacement pedicle on the ulnar aspect of the middle finger. Since there was now inadequate closure on the volar side of the middle finger, further resection was done on the proximal phalanx so that closure could be carried out.

Probably from proceeding too quickly, since a small drop of pus had been noted in the fracture site at the time of amputation of the finger, infection supervened in the tubed graft attachment. One week after operation there was marked suppuration, and the necrotic skin-graft area was excised, leaving exposed the tendon and the grafted bones with a defect of 1 cm. of soft-tissue covering. Naturally, it was felt that all was lost, but since the fixation of the graft still was intact, and it would not extrude easily on pulling, it was left alone until the following week. At this time the bone still was exposed, but on removing a tiny sequestrum it was found that the transplanted bone bled freely, and for the first time some hope was entertained for the survival of the graft. Surprisingly, under conservative care and soaks, the bone was covered completely by granulation tissue 4 weeks after the transplant had been carried out. The tendon never had extruded, and it was covered likewise. Motion was instituted in spite of the granulating wound 4 weeks after transplant. Healing was complete by June 1, some 7 weeks after surgery, and, surprisingly enough, flexion was present. The patient then instituted his own physical therapy and gained a voluntary flexion of 60°. There was a deformity on the ulnar aspect, wherein a portion of the skin graft still was attached, and in November, 1957, this attached area was used as a pedicle, and as much of the good skin from the dorsum of the amputated middle finger as could be obtained was rotated around to replace the scar on the middle finger. This time, healing was uneventful; however, the finger did stiffen up somewhat from the immobility of bandage. Three weeks after this procedure the patient returned to work and was using the finger in writing. There was very little lateral instability. Figure 3, *center and bottom*, showing the situation 15 months following the original transfer. The patient uses his finger spontaneously in writing, and he is able to pinch small objects with stability. With stabilization of the proximal phalanx, he has 60° of flexion in the middle joint. Extension of this joint is complete, though there has been some dropping of the distal joint, presumably from the adherence of the intrinsic tendons from the infection.

Graham[4] has reviewed the literature on joint transplant, both half and whole joint transplant, and presented a remarkably fine result of metacarpal phalangeal joint transplant of the thumb from a metatarsal joint.

Regarding the foregoing case report, in my opinion a better source of material would have been the middle joint of a toe, but this was not used because of the availability of the middle joint. The fact that the toe joint is smaller should be an advantage, and possibly the infection would have been prevented. To me the remarkable aspect of the case was the conclusive evidence of vascularization of the graft within 2 weeks. This was confirmed by the lack of sequestration of the transplant.

CONCLUSION

Interphalangeal joint stiffness remains a difficult problem, but it should be approached more hopefully than is sometimes the case. First of all, therapy should consist of prevention by proper immobilization and early mobilization, but, once stiffness has occurred, physical therapy, dynamic splinting and occupational therapy should be used. If these fail in restoring motion, then proper evaluation may indicate the possibility of a good result by capsulectomy or arthroplasty, joint substitution or metallic prothesis. The joint substitution method has certain functional advantages over metallic substitution, but it also has the disadvantage of a limited source of supply. In the presence of irreparable tendon and joint damage, arthrodesis with shortening of the proximal phalanx may still be indicated.

REFERENCES

1. Brannon, E. W., and Klein, G.: Experience with a new finger—joint prothesis. Proceedings American Society for Surgery of the Hand. J. Bone & Joint Surg. 40A:958, 1958.
2. Bunnell, S.: Surgery of Hand, ed. 3, Philadelphia, Lippincott, 1956.
3. Carroll, R.: Digital arthroplasty in proxi-

mal interphalangeal joint, J. Bone & Joint Surg. 36:912, 1954.
4. Graham, W. C.: Transplantation of joint to replace diseased or damaged articulation in the hand, Am. J. Surg. 88:130, 1954.
5. Kaplan, E. B.: Functional and Surgical Anatomy of the Hand, Philadelphia, Lippincott, 1953.
6. Koch, S. L.: Disability of hand from loss of joint functions, J.A.M.A. 104:30, 1935.
7. Shaw, C. G.: Metacarpal phalangeal ankylosis, M. J. Australia 2:549, 1920.

Rigiditate de Articulation Interphalangee

Summario in Interlingua

Rigiditate de articulation interphalangee, occurrente como resultato de trauma, es un major causa de invaliditate manual. In general, le effortios de corriger ille typo de rigiditate se ha exhaurite primarimente in le uso de mesuras physio-therapeutic insimul con le application de ferulas dynamic. Non-successo de iste methodos ha usualmente signalate le abandono del therapia. Es presentate un caso que demonstra le practicabilitate del transplantation de un articulation total como medio possibile de alleviar tal rigiditate. Es etiam signalate le possibilitate de usar capsulectomia in casos seligite como medio de re-mobilisar le articulation.

17.

The Psychological Reaction to Severe Hand Injury

GORDON H. GRANT, M.D.*

Any serious trauma with major surgical procedures as sequelae might be expected to leave some slight imprint on the psyche of the patient. How real that damage is is largely a matter for conjecture at the moment. Very little formal study seems to have been devoted to the matter; no appreciable volume of statistics seems to be available. This hardly is surprising; surgeons are not equipped by training or experience accurately to analyze psychic reactions, and the psychiatrists of today are hard pressed to keep up with the work load imposed by primary mental disease. It may be, too, that we regard a certain degree of psychic upset as normal immediately after serious disease or injury culminating in surgery. The anesthetic produces its own effects; the patient may have subtle or gross idiosyncracies to other drugs. A seeming manic state may result. Dehydration and electrolyte imbalance, especially hypopotassemia, may produce a profound apathy, as may infection or toxemia. These are transitory upsets, though, and in the main they are quickly put right. It seems safe to say that the great majority of patients emerge from even prolonged surgical ordeals with no detectable instability and with no measurable lowering of intelligence. Hypoxia, to any serious degree and if at all prolonged, provides an exception to this observation.

Atkinson† has pointed out that many patients bring unstable personality structures to their surgical ordeals. Senescence or outright senility may be speeded up; an involutional psychosis may be triggered. The victim of serious hand injury is not likely to fall into this category; he belongs to a younger, more active, group. However, his past history may yield clues that identify him as a candidate for serious psychological trouble, especially if his ordeal must be long and his eventual disability severe. Unhappily, the history elicited after gross hand injury does not ordinarily scan the patient's whole past. Usually we do not ask about such things as nervous breakdowns; we may fail to elicit the telling fact that this patient has been prone to accidents.

Dunbar* and other workers have adequately identified the personality pattern that goes with recurrent injury. The disturbance is likely to be deep, and it may run to a very real death wish. We are hardly equipped here to speculate profoundly on these esoteric aspects of psychiatry. But we should keep in mind the long-proven fact that people who get hurt are apt to be the tense, the hostile, the apathetic and the pathologically careless. The corollary of this is that often the stage is set for psychological trouble as we approach the victim of gross hand damage. It should be remarked that this segment of the history should be secured from the relatives. The shocked, upset patient is not a reliable

* Victoria, B C.

† Postoperative psychosis, S. Clin. North America 37:835-844, 1957.

* Susceptibility to accidents, M. Clin. North America 28:653-662, 1944.

... & Joint

4. ... of joint to replace diseased or damaged articulation in the hand, Am. J. Surg. 88:130, 1954.
5. Kaplan, E. B.: Functional and Surgical Anatomy of the Hand, Philadelphia, Lippincott, 1953.
6. Koch, S. L.: Disability of hand from loss of joint functions, J.A.M.A. 104:30, 1935.
7. Shaw, C. G.: Metacarpal phalangeal ankylosis, M. J. Australia 2:549, 1920.

Rigiditate de Articulation Interphalangee

Summario in Interlingua

Rigiditate de articulation interphalangee, occurrente como resultato de trauma, es un major causa de invaliditate manual. In general, le effortios de corriger ille typo de rigiditate se ha exhaurite primarimente in le uso de mesuras physio-therapeutic insimul con le application de ferulas dynamic. Non-successo de iste methodos ha usualmente signalate le abandono del therapia. Es presentate un caso que demonstra le practicabilitate del transplantation de un articulation total como medio possible de alleviar tal rigiditate. Es etiam signalate le possibilitate de usar capsulectomia in casos seligite como medio de re-mobilisar le articulation.

17

The Psychological Reaction to Severe Hand Injury

GORDON H. GRANT, M.D.*

Any serious trauma with major surgical procedures as sequelae might be expected to leave some slight imprint on the psyche of the patient. How real that damage is is largely a matter for conjecture at the moment. Very little formal study seems to have been devoted to the matter; no appreciable volume of statistics seems to be available. This hardly is surprising; surgeons are not equipped by training or experience accurately to analyze psychic reactions, and the psychiatrists of today are hard pressed to keep up with the work load imposed by primary mental disease. It may be, too, that we regard a certain degree of psychic upset as normal immediately after serious disease or injury culminating in surgery. The anesthetic produces its own effects; the patient may have subtle or gross idiosyncracies to other drugs. A seeming manic state may result. Dehydration and electrolyte imbalance, especially hypopotassemia, may produce a profound apathy, as may infection or toxemia. These are transitory upsets, though, and in the main they are quickly put right. It seems safe to say that the great majority of patients emerge from even prolonged surgical ordeals with no detectable instability and with no measurable lowering of intelligence Hypoxia, to any serious degree and if at all prolonged, provides an exception to this observation.

Atkinson† has pointed out that many patients bring unstable personality structures to their surgical ordeals. Senescence or outright senility may be speeded up; an involutional psychosis may be triggered. The victim of serious hand injury is not likely to fall into this category; he belongs to a younger, more active, group. However, his past history may yield clues that identify him as a candidate for serious psychological trouble, especially if his ordeal must be long and his eventual disability severe. Unhappily, the history elicited after gross hand injury does not ordinarily scan the patient's whole past. Usually we do not ask about such things as nervous breakdowns; we may fail to elicit the telling fact that this patient has been prone to accidents.

Dunbar* and other workers have adequately identified the personality pattern that goes with recurrent injury. The disturbance is likely to be deep, and it may run to a very real death wish. We are hardly equipped here to speculate profoundly on these esoteric aspects of psychiatry. But we should keep in mind the long-proven fact that people who get hurt are apt to be the tense, the hostile, the apathetic and the pathologically careless. The corollary of this is that often the stage is set for psychological trouble as we approach the victim of gross hand damage. It should be remarked that this segment of the history should be secured from the relatives. The shocked, upset patient is not a reliable

* Victoria, B.C.

† Postoperative psychosis, S. Clin. North America 37:835-844, 1957.

* Susceptibility to accidents, M. Clin. North America 28:653-662, 1944.

witness; in any case, he may conceal this part of his past.

Many of the roles that the hand must play on the stage of modern life are new. The burden of the machine has fallen on the hand in a dual sense. The machine sets a perennial ambush for the man or the woman who operates it. When the stationary machine manages to inflict injury, it is the hand that suffers two times out of three. The victim is likely to be a specialist in the narrowest sense. Even minor loss of bimanual skill may bar him from the old way of making a living; the new way may be far down the scale in earning power, in security and in prestige. Loss of a beloved hobby requiring bimanual skill may deal a far more crippling blow to the psyche than the necessity of learning a new way of making a living However, recognition of the hand's importance seems not to have penetrated to the subconscious of modern man. The hand was expendable a few centuries ago, and no doubt often was sacrificed to protect the face, the precordium or the genitalia. These emergencies are gone largely from modern life, but man seems still to carry this attitude with him as he confronts his new enemy — the machine.

Often this attitude is reflected in the earliest reactions of patients whose hands have been badly damaged. Many display an astonishing optimism regarding the speed and the completeness of their anticipated recovery Many are skeptical or incredulous when told that recovery may take weeks or months and can be only partial at best. This badly based optimism seems to endure only until the conscious, reasoning intelligence takes over Most patients of normal intelligence soon come to apply their analytic powers to the meaning of loss of sensation and voluntary motion. It is at this stage that the first severe psychological crisis is likely to occur. From this probably critical point a variety of factors determine the patient's psychological course, perhaps for the rest of his life. His basic psychological is, of course, of fundamental importance. The efficiency of surgical treatment plays a major role in determining the patient's progress. Prompt healing, with early disappearance of pain, goes a long way toward supporting the patient's morale and mental health. Conversely, delay in healing, with persistent edema, stiffness and pain, may erode even the strongest personality. However, the major factor seems to be the relationship of the patient with his surgeon. The man whose hand is badly damaged, whose whole future suddenly lies in doubt, reverts swiftly to the frame of mind of early adolescence. In this time of dubious prospects he pins, as he must, all his faith on the man who takes charge of his hand. The surgeon becomes a father figure to a far greater degree than he commonly realizes. In this crisis the patient will accept explanation and reassurance from the surgeon and from him alone. Successful reassurance must be based on as detailed an exposition of the derangement in anatomy and physiology as the patient's intelligence can assimilate. If the surgeon is casual, if he seems in any way to lack interest, the patient's fears deepen and become colored by resentment toward the man who seems to be failing him. This resentment is rarely expressed as such; in his adolescent frame of mind the patient may be incapable of voicing fear or resentment. However, if this resentment becomes strongly rooted in the patient's psyche at this stage, it is likely to color permanently his total reaction to his injury and his eventual disability.

CASE REPORTS

I should like briefly to discuss the histories of three patients who suffered severe hand disability. Each patient became psychotic, and each displayed certain reactions that have been noted to a lesser degree in other patients with severe hand damage.

The first t was a 34-year-old male who showed vious stigmata of instability. He suffe bulbar poliomyelitis. His

recovery was complete except for the right motor thenar nerve. He was discharged to his home, where he soon became increasingly dependent and tearful. He was found to be suffering from a mixed psychosis. He made a good recovery under psychotherapy. He developed good insight into his mental state and was able to give a satisfactory history of the onset of his psychosis. From the outset he had felt strongly that he was being punished for his sins. However, the chief factor seemed to be a rapid deterioration in his previously good marital relations.

He had tried to avoid touching his wife with his deformed and disabled hand, and had soon come to omit all preliminary love-making. This had aroused his wife's resentment, and their total relationship deteriorated badly. The wife was cooperative when her husband's difficulties were explained, and this played a vital role in his recovery.

The second patient, a 40-year-old male of Eastern European descent, suffered gross mangling of the right wrist and hand. The fifth finger was avulsed, segments were avulsed from both major nerves in the wrist, and all flexor tendons excepting the flexor carpi radialis were divided or partially avulsed. Skin loss was marked. Five surgical procedures produced a satisfactory cosmetic result, full return of sensation in both fields, and reasonably good function except for opponens action. Psychologically, the patient's course was most stormy. He was agitated from the outset and required heavy sedation. He was discharged to his home after detachment and implantation of the pedicle. Four days later he developed an acute manic psychosis. He had been greatly irritated by the noise made by his three small children, but his acute outbreak came hard on the heels of a failure in his only attempt at sexual relations.

This patient made a good recovery under tranquilizer medication and psychotherapy. In retrospect, it would seem that he may have been a borderline psychotic before his injury. This segment of his history was not elicited at the time His wife later supplied ample evidence out of the patient's past in the way of a hair-trigger temper, of great variation in mood, of tears. In any case, almost certainly he was already psychotic when discharged from the shelter of the hospital to face the stress of a dishevelled household.

When the patient recovered and gained full confidence in us, he revealed that he had always had strong guilt feelings. His injury seemed to him a frightful punishment for his sins He had interpreted our vigorous reassurance as stern exhortations, and this had added to his terror. Explanations of what was going to be done to reconstruct his hand were meaningless until he was shown an atlas of anatomy.

These patients illustrate at least two reactions that seem common to some degree in serious hand disability. Each had strong guilt feelings and a sense of being punished. The sexual performance of each, previously entirely adequate, deteriorated swiftly after injury to the dominant hand. These reactions appear to be a commonplace in psychiatric experience. The novelist James called attention to the castration complex long before Freud took up the subject. Injury to any extremity, but especially to the dominant hand, reverberates through the whole psyche and tends to be expressed in the male by loss of sexual confidence and performance. This, in turn, is likely to result in deterioration in all the individual's interpersonal relationships.

The third patient was a 35-year-old housewife. As later elicited, her psychological history was normal except for a tendency to perfectionism. She suffered mangling of the right hand in a power saw at home. The thumb tip was amputated, the index was resected with its metacarpal, and a flexor graft later had to be inserted in the ring finger. She was outwardly cheerful and suprisingly philosophic during her hospital stay. A week after her arrival home, her husband reported that she had not changed her clothes or brushed her hair for 4 days She was diagnosed as suffering from an affective depression. She has made a partial recovery under electroconvulsive therapy but has not regained her former independence and competence.

In dealing with this patient we simply were misled by a façade of spurious cheerfulness. A woman who had occupied the next bed was able to tell us later that, in fact, our patient had wept often at night and had expressed the wish that she had been killed rather than, as she put it, mutilated. Only a high index of suspicion, perhaps not normal to a surgeon, could have divined her real mental state. Nevertheless, the history of perfectionism, if elicited, might have served

witness; in any case, he may conceal this part of his past.

Many of the roles that the hand must play on the stage of modern life are new. The burden of the machine has fallen on the hand in a dual sense. The machine sets a perennial ambush for the man or the woman who operates it. When the stationary machine manages to inflict injury, it is the hand that suffers two times out of three. The victim is likely to be a specialist in the narrowest sense. Even minor loss of bimanual skill may bar him from the old way of making a living; the new way may be far down the scale in earning power, in security and in prestige. Loss of a beloved hobby requiring bimanual skill may deal a far more crippling blow to the psyche than the necessity of learning a new way of making a living. However, recognition of the hand's importance seems not to have penetrated to the subconscious of modern man. The hand was expendable a few centuries ago, and no doubt often was sacrificed to protect the face, the precordium or the genitalia. These emergencies are gone largely from modern life, but man seems still to carry this attitude with him as he confronts his new enemy — the machine.

Often this attitude is reflected in the earliest reactions of patients whose hands have been badly damaged. Many display an astonishing optimism regarding the speed and the completeness of their anticipated recovery. Many are skeptical or incredulous when told that recovery may take weeks or months and can be only partial at best. This badly based optimism seems to endure only until the conscious, reasoning intelligence takes over. Most patients of normal intelligence soon come to apply their analytic powers to the meaning of loss of sensation and voluntary motion. It is at this stage that the first severe psychological crisis is likely to occur. From this probably critical point a variety of factors determine the patient's psychological course, perhaps for the rest of his life. His basic psychological pattern is, of course, of fundamental importance. The efficiency of surgical treatment plays a major role in determining the patient's progress. Prompt healing, with early disappearance of pain, goes a long way toward supporting *the patient's morale and mental health.* Conversely, delay in healing, with persistent edema, stiffness and pain, may erode even the strongest personality. However, the major factor seems to be the relationship of the patient with his surgeon. The man whose hand is badly damaged, whose whole future suddenly lies in doubt, reverts swiftly to the frame of mind of early adolescence. In this time of dubious prospects he pins, as he must, all his faith on the man who takes charge of his hand. The surgeon becomes a father figure to a far greater degree than he commonly realizes. In this crisis the patient will accept explanation and reassurance from the surgeon and from him alone. Successful reassurance must be based on as detailed an exposition of the derangement in anatomy and physiology as the patient's intelligence can assimilate. If the surgeon is casual, if he seems in any way to lack interest, the patient's fears deepen and become colored by resentment toward the man who seems to be failing him. This resentment is rarely expressed as such; in his adolescent frame of mind the patient may be incapable of voicing fear or resentment. However, if this resentment becomes strongly rooted in the patient's psyche at this stage, it is likely to color permanently his total reaction to his injury and his eventual disability.

CASE REPORTS

I should like briefly to discuss the histories of three patients who suffered severe hand disability. Each patient became psychotic, and each displayed certain reactions that have been noted to a lesser degree in other patients with severe hand damage.

The first patient was a 34-year-old male who showed no gross previous stigmata of instability. He suffered a severe bulbar poliomyelitis. His

recovery was complete except for the right motor thenar nerve. He was discharged to his home, where he soon became increasingly dependent and tearful. He was found to be suffering from a mixed psychosis. He made a good recovery under psychotherapy. He developed good insight into his mental state and was able to give a satisfactory history of the onset of his psychosis. From the outset he had felt strongly that he was being punished for his sins. However, the chief factor seemed to be a rapid deterioration in his previously good marital relations.

He had tried to avoid touching his wife with his deformed and disabled hand, and had soon come to omit all preliminary love-making. This had aroused his wife's resentment, and their total relationship deteriorated badly. The wife was cooperative when her husband's difficulties were explained, and this played a vital role in his recovery.

The second patient, a 40-year-old male of Eastern European descent, suffered gross mangling of the right wrist and hand. The fifth finger was avulsed, segments were avulsed from both major nerves in the wrist, and all flexor tendons excepting the flexor carpi radialis were divided or partially avulsed. Skin loss was marked. Five surgical procedures produced a satisfactory cosmetic result, full return of sensation in both fields, and reasonably good function except for opponens action. Psychologically, the patient's course was most stormy. He was agitated from the outset and required heavy sedation. He was discharged to his home after detachment and implantation of the pedicle. Four days later he developed an acute manic psychosis. He had been greatly irritated by the noise made by his three small children, but his acute outbreak came hard on the heels of a failure in his only attempt at sexual relations.

This patient made a good recovery under tranquilizer medication and psychotherapy. In retrospect, it would seem that he may have been a borderline psychotic before his injury. This segment of his history was not elicited at the time. His wife later supplied ample evidence out of the patient's past in the way of a hair-trigger temper, of great variation in mood, of tears. In any case, almost certainly he was already psychotic when discharged from the shelter of the hospital to face the stress of a dishevelled household.

When the patient recovered and gained full confidence i[illegible]

had interpreted our vigorous reassurance as stern exhortations, and this had added to his terror. Explanations of what was going to be done to reconstruct his hand were meaningless until he was shown an atlas of anatomy.

These patients illustrate at least two reactions that seem common to some degree in serious hand disability. Each had strong guilt feelings and a sense of being punished. The sexual performance of each, previously entirely adequate, deteriorated swiftly after injury to the dominant hand. These reactions appear to be a commonplace in psychiatric experience. The novelist James called attention to the castration complex long before Freud took up the subject. Injury to any extremity, but especially to the dominant hand, reverberates through the whole psyche and tends to be expressed in the male by loss of sexual confidence and performance. This, in turn, is likely to result in deterioration in all the individual's interpersonal relationships.

The third patient was a 35-year-old housewife. As later elicited, her psychological history was normal except for a tendency to perfectionism. She suffered mangling of the right hand in a power saw at home. The thumb tip was amputated, the index was resected with its metacarpal, and a flexor graft later had to be inserted in the ring finger. She was outwardly cheerful and suprisingly philosophic during her hospital stay. A week after her arrival home, her husband reported that she had not changed her clothes or brushed her hair for 4 days. She was diagnosed as suffering from an affective depression. She has made a partial recovery under electroconvulsive therapy but has not regained her former independence and competence.

In dealing with this patient we simply were misled by a façade of spurious cheerfulness. A woman who had occupied the next bed was able to tell us later that, in fact, our patient had wept often at night and had expressed the wish that she had been killed rather than, as she put it, mutilated. Only a high index of suspicion, perhaps not normal to a surgeon, could have divined her real mental state. Nevertheless, the history of perfectionism, if elicited, might have served

to warn us that her outward reaction was grossly abnormal; might have enabled us to avert her depression.

It developed later that our relationship with this patient had been most unsatisfactory, although we had thought it to be excellent. We fell in step with the patient's apparent stoicism and cheerfulness. She interpreted our resulting casual attitude as evincing a lack of interest and sympathy, and her continuing outward cheerfulness concealed a profound resentment.

Observations of these and other patients, together with conversations with several psychiatrists, seem to point up certain useful facts. Usually, the patient and the surgeon are mutual strangers; each must attempt to guess at what is going on in the other's mind. Certain outward reactions on the patient's part are useful signposts. Apathy, lethargy or anorexia, in the absence of infection or other causative physical factors, may indicate a severe degree of depression. Conversely, as we have seen, an abnormal cheerfulness may mask these inner feelings and may signal warnings of serious and imminent trouble. Tears, shed by an adult male who has not been known by those close to him to weep in time of crisis before, warn of depression that may already verge on the psychotic.

When the surgeon has done his best for the hand structurally, when he has tried to understand and encourage the patient psychologically, he still may find himself up against that most baffling problem—the patient who looks on his disability as a newfound friend. He may refuse to be parted from that new friend. Many members of society, it seems, find the battle of life almost too frightening or too tedious to endure. The temptation to retire from the battle is recurrent and strong. Many psychoneurotic individuals do in effect retire early and often in life. The man with a badly damaged hand has acquired, he feels, a respectable excuse for not going back to the battle. If his injury is in any way compensable, his resistance to rehabilitation is reinforced powerfully. This man may defeat the best efforts of the most determined surgeon, even when these are backed by a knowledgeable physiotherapist. I suggest that each victim of serious hand injury might benefit greatly from a more organized effort by society to help him. We all know what can be done for the amputee: from the moment of amputation he is surrounded by a group of knowledgeable, dedicated people who support him, teach him to accept and use his prosthesis and, finally, shepherd him as he goes out to learn a new way of life. The man who manages to lose only part of his hand often is in worse case than the amputee. In many areas of society no such organized help is available to him. Over the long haul, many of these patients do not fare as well socially and economically as we surgeons might like to believe. The psychological support afforded the amputee looms as large as his physical re-education. After all, he plays the central role in the drama that is set in motion by his injury. He is motivated powerfully by a desire not to let the rest of the cast down. Given a chance, the victim of nonamputative injury unquestionably would respond as well as the amputee.

SUMMARY

1. Profound physiologic disturbances are not common in the wake of damage to the extremities if certain factors such as the crush syndrome and hypoxia are excepted. Bizarre behavior on the part of a patient who has suffered injury to an extremity and has undergone surgery to repair the damage should be regarded as evidence of true psychological derangement until a psychiatrist has testified to the contrary.

2. Individuals who suffer repetitious injury are likely to be tense, hostile, apathetic or pathologically careless.

3. A variety of factors influence the de-

gree and the rate of the patient's psychological recovery after serious hand injury. Of these, the most important probably is the relationship between patient and surgeon.

4. Many individuals who suffer serious injury revert swiftly to the behavior patterns of adolescence. This frame of mind may produce bizarre, paradoxic reactions toward the surgeon and others who take care of them.

5. A plea is entered for a more organized effort by society to help the individual who loses only part of his hand. At present, often he is in worse case economically and psychologically than the man who loses his hand outright.

Le Reaction Psychologic a Sever Vulneration del Mano

Summario in Interlingua

Vulneration de un extremitate e manipulationes chirurgic pro reparar le injuria non produce, [illegible] generalmente parlar, sever formas de disturbation physiologic, excepte in caso de certe complicationes, como per exemplo hypoxia. Le comportatmento bizarre del patiente post un tal vulneration e post tal manipulationes es probabilemente non le resultato de un disturbation physiologic sed plus tosto de un ver disrangiamento psychologic.

Personas qui es vulnerate—specialmente si isto occurre repetitemente—suffre, con alte grados de probabilitate, de un de plure formas de defecto characterologic. Il es importantissime recognoscer le signos de tal defectors in le curso del tractamento pro averter, si possibile, le disveloppamento de un serie morbo psychic.

Es citate le historias de tres patientes. Cata un del tres deveniva psychotic post le vulneration [illegible] durante le tractamento. Cata un del tres habeva exhibite un certe grado de instabilitate psychic ante le vulneration, sed in nulle del casos esseva iste facto establite per questionation. Es signalate que le historia psychologic de patientes vulnerate es rarmente coperite per le questionation. Iste manco pote devenir un serie obstaculo pro le successo del tractamento.

In le plus grande parte de Nord-America, amputatos recipe al tempore presente formas multo plus comprehensive e efficace de tractamento que le subjecto qui perde solmente un parte de su mano. Iste ultime responderea sin dubita non minus ben que le amputato al complete supporto psychologic, economic, e sociologic.

18

Diagnosis and Treatment of Tumors of the Hand

R. H. Clifford, M.D., and A. P. Kelly, Jr., M.D.*

In the hand, benign tumors are common; malignant tumors, quite rare. The general incidence of malignant primary tumors of the hand is only .62 per cent of all the malignant tumors seen at Henry Ford Hospital over a period of 30 years.[2]

The authors consider the treatment of tumors of the hand to be exclusively surgical. The most favorable aspect of surgery for tumors of the hand is the ability to work in an absolutely bloodless field, which gives the surgeon an unexcelled opportunity for exact dissection. These tumors are freely accessible, and the benign lesions can be removed completely through properly placed incisions without jeopardizing the normal functional anatomy of the hand. In malignant lesions, the complete removal of the tumor is equally feasible, although sacrifice of normal tissue is indicated. Reconstructive surgery of the hand has advanced to a point where functional restoration can be accomplished even after radical excision of major portions of the hand.

The tumors will be discussed under three headings. skin, soft tissue, bone.

TUMORS OF THE SKIN

Among the commonest tumors of the hand are the keratoses. These growths, usually diagnosed by the characteristic appearance, may be treated and cured by either surgery or electrodesiccation The many dermatoses affecting the hand are not considered here, but attention should be drawn to the senile dermatitis, especially arsenical dermatitis, because of its importance as a precancerous lesion. The individual and isolated lesion of these conditions should be excised, and it can be done with a narrow margin. However, wherever these lesions are found, it is not unusual to find a continuing crop of new ones developing.

Irradiation dermatitis is a frequent forerunner of malignant degeneration. The very mild lesion showing the characteristic telangiectasia must be kept under careful observation. If there is a tendency to scaling or to ulceration, the entire area should be excised and resurfaced with a split-thickness skin graft.

Moles are not frequent on the skin of the hand. When these lesions occur on the palm skin, as in the sole of the foot, almost always they are of the junctional type, and the possibility of degeneration into malignant melanoma must be considered. They should be excised as an elective procedure.

Malignant melanoma occurs in both the skin of the hand and in the nailbed, subungual melanoma being more frequent than that of the skin itself This tumor may be of [illegible] When [illegible] lucency of the nail, and a tumor so colored under the nail leads to a high index of suspicion Because of the lethal character of this tumor, the slightest suspicion of mela-

---

* Detroit, Mich.

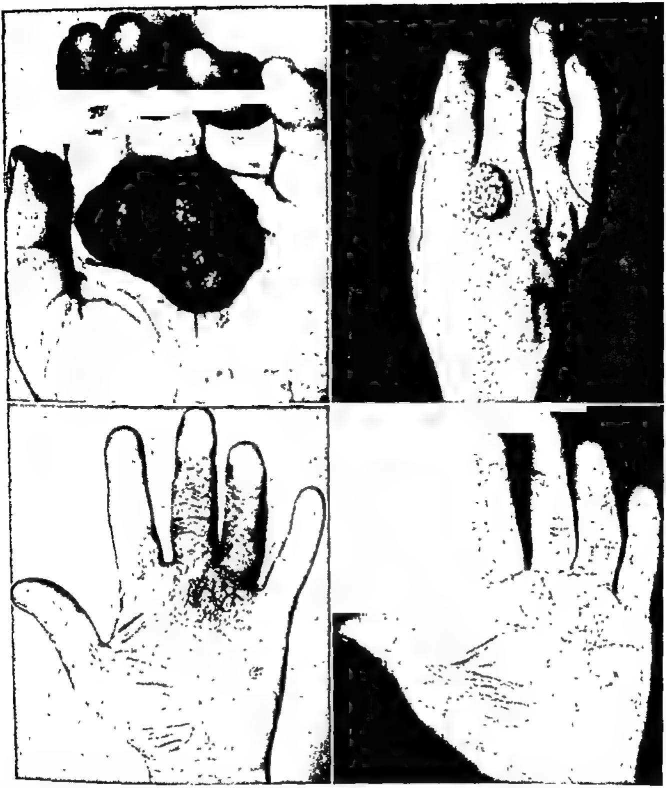


FIG. 1. (*Top, left*) Pyogenic granuloma (*Top, right*) Epidermoid carcinoma. (*Bottom, left*) Intra-epithelial squamous cell carcinoma. (*Bottom, right*) Postoperative split-skin graft.

noma in the differential diagnosis requires the patient's knowledge and consent that amputation of the finger will be carried out if the frozen section confirms the diagnosis of melanoma. An entire ray amputation is the treatment of choice. The amelanotic melanoma presents a more difficult clinical diagnosis. In any subungual tumor that deforms the nail or continues to drain as a chronic whitlow, the possibility of amelanotic

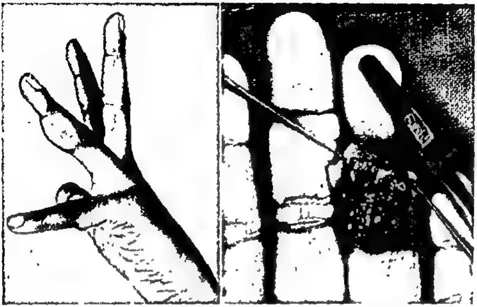


FIG 2. (*Left*) Hemangioma. (*Right*) Tumor at operation.

melanoma must be ruled out by biopsy. Melanoma on the skin of the hand requires a wide local incision, and, if the tumor is advanced, a hemiamputation of the hand may be indicated. In cases with clinical evidence of regional lymph-node involvement, a radical dissection of the node-bearing areas should be carried out. The consensus is that this operation should be delayed several weeks following the primary removal of the tumor. In cases with no clinical evidence of lymph-node involvement, the decision for radical node dissection is more difficult but often is done a priori. In these latter cases there is, as yet, no significant evidence of the efficacy of radical dissection to warrant its routine employment [8]

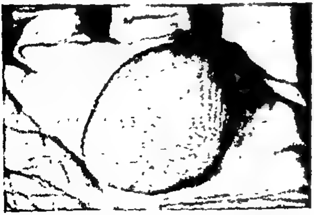


FIG. 3. Fibroma on the palm of the hand.

One of the most common surface tumors of the hand is the pyogenic granuloma This may range from a tiny excrescence to a monstrous granuloma (Fig. 1, *top, left*). Occasionally, the question of malignant tumor may enter into this diagnosis, but the soft boggy consistency, the tendency to hemorrhage on the slightest trauma and, usually, small or pedunculated base should lead to a clinical diagnosis.

Malignant tumors of the skin are encountered most often on the dorsal surface. Epidermoid carcinoma is about ten times more frequent than basal cell type. We have seen no epidermoid carcinomas arising on the palm except from pre-existing lesions.

Figure 1, *top, right,* shows a typical epidermoid carcinoma, the treatment of which is wide excision and covering with a split-thickness skin graft. Figure 1, *bottom, left,* shows an extensive intra-epithelial carcinoma treated by complete excision and the covering of the total area with split-thickness grafts. The postoperative photograph (Fig. 1, *bottom, right*) is included to demonstrate the adaptability of split-thickness graft to the form and the function of the hand, even to the re-forming of the normal skin lines.

Hopes of primary suture closure often leads to inadequate removal of these seemingly discrete lesions.

Dissection of the axillary nodes in cases of carcinoma of the hand should be carried out if any nodes are palpable along the lymphatic course. When the tumor has been ulcerated, we recommend a delay of several weeks, as often the nodes disappear after the primary ulcer heals. When no nodes are palpable, we do not recommend prophylactic axillary dissection, agreeing in this matter with the work of Taylor *et al.*[3] Exceptions to this course of treatment may be made when tumors are found to penetrate below the level of the sweat glands in the skin, as shown by the findings of Johnson and Ackerman.[4]

SOFT-TISSUE TUMORS

Hemangioma of the soft tissue of the hand is common. This tumor is diagnosed by its soft spongy feel on palpation, by the ability to empty it by digital pressure and by the usual presence of the bluish discoloration shining through the skin. Occasionally, when these tumors lie more deeply and are confined by anatomic barriers, they do not exhibit these diagnostic signs. Figure 2, *left*, shows a tumor in which there was no telltale color sign and it was quite firm to palpation. Figure 2, *right*, shows this tumor herniating from the wound as it was released from the confines of the digital fascia. Surgical excision has cured it.

In our experience, glomus tumors have been diagnosed primarily by the presence of unexplained highly localized pain; in only one case was the classic bluish-red spot visible beneath the nail. Usually the tumor is discrete and can be excised readily.

Ganglia occur in the hand but do not occur with the frequency of those occurring in the wrist proper. Usually, this tumor in the hand is found deep on the volar surface. Pain and discomfort are present occasionally, but more often the mass is found by the patient on self-examination after minor trauma to the area. Care must be taken upon removal of this mass to include the point of attachment to the tendon sheath or joint capsule whence it arises.

FIG. 4. Schwannoma.

When the ganglion arises on the distal phalanges, especially on the dorsum of the distal phalanges, it is easily confused with several other lesions in this location. The mucous cyst and the rheumatic nodule both simulate a ganglion but can easily be distinguished clinically. Usually, the rheumatic nodule is firmer and appears to be more fixed. The mucous cyst shows about the same consistency as a ganglion but almost always appears to be intracutaneous, giving the impression of transparency.

Solitary fibromas are noted as firm, painless lumps and are found to arise in any level of the soft tissue of the hand. Those arising in the more superficial structures

FIG. 8. Thrombosis of the ulnar artery.

a soft crepitation on palpation, the reason for which is illustrated in Figure 7, *left.* The treatment for this is complete excision of all diseased tissue, including the parietal and vaginal portion of the tendon sheath. Other nonpyogenic infections, such as tuberculous dactylitis or fungal infection, may simulate tumors and require a place in the differential diagnosis. Occasionally, subcutaneous calcium deposits may so change the skin over them as to suggest an early carcinoma (Fig. 7, *right*).

Aneurysms of the manual vessels are not common When they do occur, they may present the classic signs of aneurysm found elsewhere. However, if thrombosed, the diagnosis is more difficult and can be made only on surgical exploration. Figure 8 shows a thrombosed aneurysm arising in the ulnar artery. Even if these lesions are not thrombosed, there should be no hesitation about ligating and sectioning the affected artery, as the palmar arch ensures adequate collateral circulation.

Early Dupuytren's contracture may present only as solitary or multiple tumors in the palm, but usually the diagnosis is made without difficulty. The treatment of this condition is well established and in most cases consists of complete palmar fasciectomy, although in selected cases a Luck fasciotomy affords excellent relief.

BONE TUMORS

Enchondroma is the commonest bone tumor appearing in the hand. The roentgenologic appearance is characteristic, with radiolucency and thinning of the cortex, and usually the lesion is in contact with the epiphysis (Fig. 9, *left*). Loculation sometimes is noted, and occasional flecks of calcium are seen. Often these tumors come to the attention of the surgeon when the patient

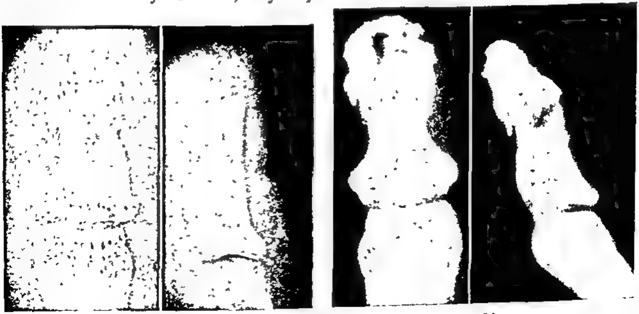


FIG 9 (*Left*) Enchondroma (*Right*) Epidermoid cyst of bone.

has suffered a pathologic fracture through the thin shell. Treatment is complete curettement of the cavity and, if it is large, the filling of it with bone chips. We do not believe that the cavity should be painted with various caustic solutions, since this is not necessary if the cavity is curetted adequately.

Epidermoid cysts can occur within the bone of the phalanges and are seen most frequently in the terminal phalanx. They have a characteristic picture of a solitary expansile lytic area in the bone without trabeculation (Fig. 9, *right*). The treatment is surgical exposure of the cyst through its bony wall, inside which will be found a well-defined cyst wall that can be dissected out. If there is any doubt of the complete excision, further curettement of the entire cavity should be done. Here, also, if the defect is large, it may be filled with bone chips.

The occurrence of exostoses in the bones of the hand is uncommon in our experience. Their roentgenologic appearance is characteristic, and the treatment is removal only if they give rise to untoward symptoms or it is demanded by the patient.

Osteomas and osteoid osteomas are rare hand tumors. Figure 10 shows a true osteoma in an unusual location.

Primary malignant tumors of the bone of the hand are exceedingly rare. After perusing the large series of bone tumors collected by Geshickter and Copeland,[3] one is impressed by the paucity of tumors involving the hand.[3] In this clinic only three such tumors have been encountered, and all were diagnosed after operative intervention It is difficult, considering the rarity of these lesions, to outline any consistent features of these tumors. As one might surmise, the treatment is wide excision with amputation of the affected and, possibly, the contiguous, digits or rays. Osteogenic sarcoma appears to have a more favorable prognosis in the hand than in other locations.[1] Ewing's sarcoma and chondrosarcoma—we have seen one of each—are exceedingly rare.

Metastatic tumors occurring in the bones of the hand often are overlooked because of the failure to include the hand in the normal roentgenologic survey for metastatic disease.[5] The hand may be the first evidence of malignancy elsewhere. This was the situation in one of our three metastatic lesions of the bones of the hand. Two of the cases were from carcinoma of the lung; the third, from a hypernephroma metastatic to both thumbs. The last case was the only one in which the diagnosis was suspected preoperatively.

Fig. 10. Osteoma.

REFERENCES

1. Carroll, R. E.: Osteogenic sarcoma in the hand, J. Bone & Joint Surg. 39A:325-331, 1957.
2. Clifford, R. H., and Kelly, A. P., Jr.: Primary malignant tumors of the hand, Plast. & Reconstruct. Surg. 15:227-232, 1955.
3. Geshickter, C. F, and Copeland, M. M.: Tumors of Bone, ed. 3, Philadelphia, Lippincott, 1949.
4. Johnson, R E., and Ackerman, L. W.: Epidermoid carcinoma of hand, Cancer 3:657-666, 1950.
5. Kerin, R.: Metastatic tumors of the hand, J. Bone & Joint Surg. 40A:263-278, 1958.

19

Arthrodesis of the Knee Joint

F. H. Moore, F.R.C.S. (Ed.), and I. S. Smillie, F.R.C.S. (Ed.)*

This chapter reports the results of a review of 126 consecutive arthrodeses of the knee performed on 116 patients during the past 14 years. The review was undertaken (1) to determine the reasons for operation; (2) to find out whether the immediate outcome or the final result depended on the type of operation, technic or after-treatment; (3) to determine whether errors of technic or management detracted from the value of the procedure; and (4) to see if in the course of the review any points arose in the management of the arthritic knee that might help to avoid or to defer the necessity for surgery.

The operations were performed for the reasons indicated in Table 1. As anticipated, rheumatoid arthritis and tuberculosis formed the largest group and accounted for 70 per cent of the total. The numbers of other conditions, particularly those associated with wear-and-tear (or osteo) arthritis, did not conform to preconceived clinical impressions and will be the subject of comment.

RHEUMATOID ARTHRITIS

Rheumatoid arthritis is a polyarthritis, and the indication for operating on one of multiple lesions is to provide one painless stable weight-bearing limb.

It is a tragedy of rheumatoid arthritis that even in the fortunate cases, in which active disease burns out at an early date, almost invariably osteoarthritis is superimposed on the weight-bearing joints. Moreover, the response to conservative treatment is less good than in osteoarthritis of purely wear-and-tear origin. Arthodesis frequently is the eventual outcome, but it seldom becomes necessary until a number of years after the onset of symptoms. In this series of 65 cases the average interval was 12 years. There are occasions, where acute symptoms fail to settle, when operation is required at a much earlier stage. Three patients were under 25 years of age.

Bilateral Cases. Nine of the 10 bilateral operations were for rheumatoid arthritis, which appears to be the only common condition in which arthrodesis of both knees is required. All had been bedridden for long periods, 1 for over 20 years. Therefore, it is not surprising that great difficulties were

Table 1. Reasons for Operation

Diagnosis	Number of Knees	Number of Patients
Rheumatoid arthritis	65	56
Tuberculosis	24	24
Osteoarthritis (primary) ..	8	8
Osteoarthritis (secondary).	8	7
Infections	10	10
Paralysis	5	5
Gunshot wounds	2	2
Post-traumatic	1	1
Villonodular synovitis	2	2
Congenital deformity	1	1
Total..........	126	116

* From the *Department of Orthopaedic Surgery*, University of St. Andrews, Queen's College, Dundee, Scotland.

experienced in rehabilitation and that 3 patients returned home only to become bedridden once more. Of the remainder, 4 were improved to a degree that enabled them to run their own homes; 1 died from an unconnected cause soon after operation; and 1 was walking on leaving hospital but could not be traced afterward.

It is in cases where multiple joints are affected that the position of arthrodesis is of greatest importance. In 1, the knees were arthrodesed in 30° flexion despite rigid equinus deformities of feet and ankles. This patient failed to walk again, even with the help of surgical boots. Clinical judgment is clearly of importance.

The tenth bilateral case, one of gross genu valgum with secondary osteoarthritis, contrasted with the rheumatoid arthritis cases in her rapid rehabilitation and excellent final result. At 80 she is able to run her house and look after herself unaided.

The principal difficulty encountered by bilateral cases is inability to stand up from a sitting position. This may be the only factor preventing complete independence. The solution is not easy. A "horizontal bar," placed conveniently in a doorway, can be used by a patient in a wheel chair to draw himself to his feet. With an armchair, the problem is even more difficult. It may sometimes be solved by a simple overhead arrangement on the lines of a bed "parrot pole."

TUBERCULOSIS

Spontaneous ankylosis does not normally occur in tuberculosis uncomplicated by secondary infection. The principal reason for arthrodesis was the view that a stable safe joint is unattainable by conservative means once destruction of cartilage and bone has occurred. The operation has the added advantage that diseased synovial membrane and bone can be eliminated. However, it is clear that chemotherapy has altered the prognosis in tuberculosis of joints, and the necessity for arthrodesis can be expected to decline.

In this series, 24 knees were subjected to operation. In no case was there recurrence of infection or residual sinus. However, the group contained the only instance of failure to secure bony union at the first attempt. It occurred in a woman with gross destruction of bone and a thigh so fat that absolute immobilization was impossible. No means of fixation other than plaster was employed. The operation was repeated 2 years later, the compression method being used, and met with success.

OSTEOARTHRITIS

Primary. Osteoarthritis is the most common degenerative condition of the knee for which medical advice is sought. Therefore, it may seem strange that in 14 years only 8 came to operation.

It has been said that of the joints prone to osteoarthritis, the knee is the only one in which conservative measures are effective. Furthermore, gross radiologic changes are compatible with good function, provided that full extension is possible and that protection by the quadriceps is maintained. But the development of a minor flexion deformity is sufficient to precipitate symptoms. In these circumstances the erect position can be maintained only with the quadriceps in continuous contraction and the patella pressed hard against the femoral condyles. To produce an improvement, all that is necessary is to secure a return of full extension with an accompanying redevelopment of the quadriceps. Only rarely do these measures, adequately enforced, fail to provide relief.

In this connection, the use of deep roentgen therapy in the treatment of osteoarthritis is to be condemned. Pain is not relieved, and, in 2 cases of the series, not only did necrosis of bone constitute a major technical problem at operation but union and skin healing were delayed for many months.

Secondary. The cases to which this heading refers are those where degenerative changes were clearly the result of injury or

FIG. 1. Methods of arthrodesis used in the series. (*Left*) Single massive graft; (*center*) fixation by crossed Steinmann pins; (*right*) compression technic.

deformity. Osteoarthritis arising in this way responds equally well to conservative measures, and arthrodesis is rarely required except in the presence of extreme or increasing deformity. Osteoarthritis superimposed on rheumatoid arthritis presents a different problem and is considered separately.

The group contains 8 cases only, 6 of which were the result of deformities and 2 of old semilunar cartilage lesions. Despite the frequency of intra-articular fractures, particularly of the lateral condyle of the tibia, only 1 could be attributed to such a cause. This observation contrasts with other series (DePalma, 1954) and may be explained by different indications for operation rather than superiority in the results of treatment of the original injury.

It is clear from these findings that only in exceptional circumstances have radical measures any place in the treatment of gross knee injuries. What may be true of the ankle joint is certainly not true of the knee. There is every chance that after even a severe injury, provided that the maximum possible protection is afforded by quadriceps development, a good serviceable joint will result. Radiologic appearances alone, no matter how gross, are not an indication for operation. The effect of 3 months of quadriceps exercises is always worth a trial.

PARALYSIS

In paralysis, whether from anterior poliomyelitis or injury to the femoral nerve, the usual indication for operation is instability of the knee. In such circumstances arthrodesis permits the patient to discard supporting apparatus. It is only justifiable where there is no other reason for the wearing of an appliance. Therefore, the circumstances in which arthrodesis is indicated in anterior poliomyelitis are rare.

In this series, 5 knees only were arthrodesed, 4 because of anterior poliomyelitis and 1 as a result of paralysis of the quadriceps due to gunshot wounds. All were able to discard apparatus. One case of poliomyelitis required a triple arthrodesis in addition to arthrodesis of the knee.

Usually, a patient has little difficulty in making up his mind about arthrodesis when the joint concerned is painful; but it is a serious decision to eliminate a mobile painless knee joint. In these circumstances assistance may be afforded by creating the conditions of arthrodesis by the application of a plaster-of-Paris cast. When this has been worn for a few weeks, it will be clear whether or not arthrodesis is of advantage.

TECHNIC OF ARTHRODESIS

A number of operations were used. In

each a total excision was performed through an anterior incision. The only difference in the procedures was the form of fixation employed.

1. **Excision and Bone Graft.** In 5 cases, at the beginning of the series, cross grafts (Brittain, 1942) were used. In the remaining 44, a single massive graft was employed (Hatt, 1940). In general, the after-treatment consisted of a compression bandage incorporated in a Tobruk-type plaster replaced at 3 weeks by a full plaster hip spica. The patient remained off his feet for 3 months, after which the spica was discarded in favor of a thigh-length walking plaster cuff. (Fig. 1, *left*)

2. **Excision and Fixation Pins.** This time-honored technic was used in 32 cases. After excision the bone ends were held in position by Steinmann pins inserted crosswise and entered through the tibia into the femur. The pins were removed at the end of 4 weeks, when a skin-tight plaster cuff was applied, and weight-bearing was instituted. (Fig. 1, *center*)

3. **Compression.** This method, described by Key (1932) and developed by Charnley (1948), was used in 35 cases but did not include any children. The compression apparatus and pins were removed after 4 weeks, and weight-bearing in a plaster cuff was allowed. (Fig. 1, *right*)

4. **A miscellaneous group of 10 cases** was made up mainly of children, in whom

staples, stainless-steel sutures or no internal fixation at all was used.

At the beginning of the series, bone grafts were used in the majority of cases. The cutting and the inserting of bone grafts add greatly to the length and the severity of the operation, and, as simpler forms of internal fixation are at least as effective, this technic was abandoned. More recently, the crossed-pins technic or compression arthrodesis has been used almost exclusively.

The outcome of the operation did not appear to be affected in any way by the technic employed. This series contained 1 case only that failed to unite at the first attempt. It is clear, too, that with the passage of time and increase in experience, the period of rigid immobilization became progressively less, irrespective of the method used (see graph on p. 218). This may have been partly the result of earlier weight-bearing in the later cases; but it is difficult to judge to what extent the improvement was due to excessive caution exercised in the earlier cases.

As to fusion time (Table 2), again there is not much choice as regards the various technics, except that when opposed bone ends are sclerosed, union is likely to be slow and compression appears to hold an advantage. It may be a disadvantage in conditions where the bone ends are rarefied and fragile (Fig. 2). Too much importance should not be placed on the time taken for fusion to occur. A patient with a stiff knee is scarcely more inconvenienced with a plaster cuff than without. He is able to walk and sometimes can return to work.

FIG. 2. Complication of compression arthrodesis: case of rheumatoid arthritis of long standing in which the bone ends had to be shortened in order to attain the extended position. The compression method caused impaction and further shortening.

TABLE 2. FUSION TIME

Type of Operation	Number of Cases	Average Time for Fusion
Bone graft	49	21 weeks
Crossed pins	31*	19 weeks
Compression	35	14 weeks

* There were no operative deaths. One patient who suffered a hemiplegia and died 9 days after operation is not included.

POSITION

Both appearance and function are affected by the position of fusion; therefore, the degree of flexion, rotation and valgus must be chosen and maintained with care.

1. **Flexion.** Flexion varied between 0° and 30°, the average being about 10°. In general, function was best when the knee was straight or nearly so, and increasing flexion resulted in difficulty in getting the heel to the ground. Walking troubles were

FIG 3. Error of technic: in extension the tibial tubercle is lateral to the center of the patellar notch. Failure to appreciate this point results in an ugly and a disabling internal rotation deformity.

more pronounced when foot and ankle movements also were limited, as compensatory dorsiflexion could not take place. Therefore, the position of extension is especially desirable in conditions involving multiple joints, e.g., rheumatoid arthritis.

In 2 cases with long-standing deformities a flexed position was chosen in order to avoid stretching important structures behind the knee In both, the result was poor. The outcome might have been better had the deformity been corrected by the removal of a wedge of bone Shortening would not have constituted as severe a handicap as flexion.

When arthrodesis is performed in childhood, a flexion deformity may develop with growth. This occurred once amongst the 6 children of under 15 years of age The child concerned, a boy of 10, developed a 45° deformity within 3 years of operation and required corrective osteotomy. The cause is unknown. Age does not appear to be of importance, as 4 younger children did not develop deformities; nor in this instance was there any reason to suspect damage to the epiphyseal plate.

In another case an infection in infancy caused damage to the lateral femoral condyle and epiphyseal plate. Gross angulation and shortening resulted. Arthrodesis, followed later by femoral osteotomy, corrected the alignment, but the problem of shortening remained.

2. **Rotation.** On 2 occasions rotational deformities resulted from operation, the tibia in each case being rotated internally upon the femur. Errors of rotation are the result of failure to appreciate the normal relationship of femur to tibia. It is the screw-home movement which determines that the tibial tubercle is lateral to the mid-line of the patellar (trochlear) notch in extension and not opposite to it. This is not evident once the main landmark (i.e., patella) has been removed (Fig. 3).

Rotational deformities are unsightly and cause difficulty in walking; moreover, the altered alignment causes strains on both hip and tarsal joints, and may predispose to abnormal wear and tear.

3. **Lateral Angulation.** The position varied between 17° valgus and 11° varus. Even at the extremes there was no impairment of function. Therefore, the main consideration is the appearance of the limb. The normal position of 9° valgus is difficult to attain at times, and incomplete correction may be accepted occasionally if undue shortening is avoided thereby. In this series, when a valgus position was chosen, weight-bearing was deferred for at least 6 weeks

LIABILITY TO INJURY

The vulnerability of the limb appears to be increased by arthrodesis. Twelve patients are known to have sustained fractures that could be attributed directly to the operation,

and it is unlikely that the list is complete. The risk is greatest in the period immediately following removal of the plaster cast. Six fractures were reported at this stage: 5 of the tibial shaft and 1 of the femur. Three of the 6 were stress fractures: 1 affected the femoral shaft and 2 the shaft of the tibia.

The remaining 6 fractures occurred at a much later stage and appeared to be related directly to the loss of flexibility in avoiding a hazard. Five affected the femoral neck; 1 was a Pott's fracture. One other patient sustained a fracture at the joint line 7 years after operation.

SUMMARY

1. A review is presented of 126 consecutive arthrodeses of the knee performed in the course of 14 years.

2. A feature of the series was the small number of cases of osteoarthritis coming to operation despite the number of knee-joint injuries that the unit attracts.

3. At operation the most important consideration appeared to be the relationship of opposing femur to tibia, especially with regard to flexion. The straight position gave the best function in the majority of cases.

4. The results of different technics, particularly as to rate of fusion, are compared.

5. The final result was not influenced by the method employed.

6. It is shown that the operation increases the vulnerability of the limb to injury.

BIBLIOGRAPHY

Brittain, H. A.: Architectural Principles in Arthrodesis, Edinburgh, Livingstone, 1942.

Charnley, J. C.: Positive pressure in arthrodesis of the knee joint, J. Bone & Joint Surg. 30B: 478-486, 1948.

DePalma, A. F.: Diseases of the Knee, Management in Medicine and Surgery, Philadelphia, Lippincott, 1954.

Hatt, R. N.: The central bone graft in joint arthrodesis, J. Bone & Joint Surg. 22:393, 1940.

Key, J. A.: Positive pressure in arthrodesis for tuberculosis of the knee joint, South. M. J. 25:909, 1932.

Arthrodesis del Articulation del Genu

Summario in Interlingua

1 Es presentate un revista de 126 consecutive arthrodeses del genu, effectuate in le curso de dece-quatro annos.

2. Un characteristica del serie esseva le micre numero de casos de osteoarthritis includite in illo.

3 Al operation, le plus importante consideration es apparentemente le relation positional inter femore e tibia Position nonflectite produceva le melior function in le majoritate del casos.

4. Le resultatos de differente technicas es comparate, specialmente con respecto al rapiditate del fusion.

5. Le resultato final non esseva influentiate per le methodo usate.

6. Es monstrate que le operation augmenta le vulnerabilitate del gamba in caso de accidente.

20

The Role of the Disks of the Sternoclavicular and the Acromioclavicular Joints

ANTHONY F. DEPALMA, M.D.*

Clinical evaluation of the disorders of the shoulder girdle reveals that the sternoclavicular joint is rarely the cause of pain and dysfunction, whereas the acromioclavicular joint frequently is implicated. This fact was brought into sharp focus when the case histories filed in the Shoulder Clinic of the Department of Orthopaedic Surgery of the Jefferson Medical College Hospital were reviewed. That the acromioclavicular joint is a frequent site of trouble is generally not appreciated, even by many orthopaedic surgeons. When one considers the functional mechanism of the two joints, one wonders why the sternoclavicular joint is capable of withholding in abeyance the ravages of stress and strain incident to function, whereas the acromioclavicular joint is incapable of doing so and early in life shows advanced degenerative changes. The study recorded here reveals that the integrity of these joints depends upon two factors—the anatomic configuration, and the size and the preservation of the intra-articular disks.

MATERIALS AND METHODS

One hundred and fifty-one sets of sternoclavicular and acromioclavicular joints provided the material for the gross study of this investigation. They were obtained post mortem from individuals ranging in age from premature infants to 94 years. Included in this study were only subjects whose hospital records on routine questions revealed no clinical manifestations indicative of joint involvement and whose physical examination elicited no joint abnormalities. The joints were removed intact without disturbing the enveloping soft tissues. Next, both the sternoclavicular and the acromioclavicular joints were prepared in such a fashion by sharp dissection that both the articular surfaces and the intra-articular disks, if present, were clearly visualized (Fig. 1). All joints were placed in a 10 per cent solution of formaldehyde, where they remained until they were studied macroscopically. The joints then were arranged in chronologic order to correlate better the findings from decade to decade. Depending on the severity of the alterations in the articular cartilage, the synovial membranes and the intra-articular disks, the changes were graded from 1 to 4 plus.

OBSERVATIONS NOTED RELATIVE TO THE DISKS OF THE STERNOCLAVICULAR JOINTS FROM THE FIRST TO THE TENTH DECADE INCLUSIVE

Study of the specimens in the first decade exhibited considerable variation in the level of development of the sternoclavicular joint. These specimens ranged from 12 months to 3½ years. In addition, 4 sets of joints from 2 premature infants of 7 months' gestation were included in this decade A well-formed

* Jefferson Medical College Hospital, Philadelphia, Pa

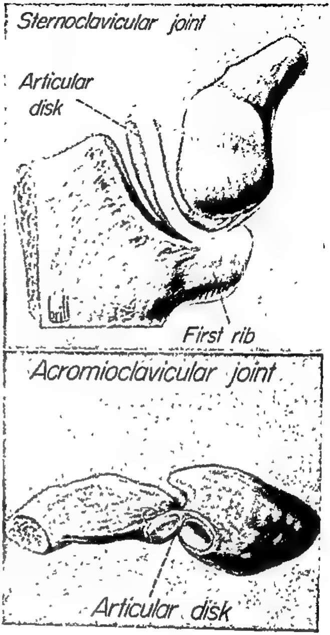


FIG. 1. (*Top*) Drawing of a sternoclavicular joint prepared for study. The disk is mobilized, and the head of the clavicle is rotated upward and backward. All articular surfaces are visualized readily. (*Bottom*) Drawing of an acromioclavicular joint prepared for study by sharp dissection. The articular surfaces of the acromion and the clavicle and the articular disk (if present) are clearly seen. (DePalma, A. F.: Degenerative Changes in the Sternoclavicular and Acromioclavicular Joints in Various Decades, Springfield, Ill., Thomas)

synovial cavity was discernible on either side of the intra-articular disk in the sternoclavicular joints obtained from the premature infants. On the other hand, the sternoclavicular joints obtained from a child 16 months of age exhibited no evidence of a synovial cavity on either side of the disk; as a matter of fact, it was necessary to employ sharp dissection to separate the disks from the adjacent surfaces of the clavicles and the sterna. However, after 23 months of age, all joints examined disclosed well-formed synovial cavities on either side of the intra-articular disks dividing the joint into two separate compartments. It was not until the third decade was reached that the sternoclavicular joints achieved the highest level of development. Then the disks assumed a convex-concave configuration slightly thinner at the centers than at the peripheries. They were stout structures consisting of fibrocartilage interposed between the two articular components of the joint. It was interesting to note that a study of the joints of all decades disclosed that there were two anatomic varieties of the disk: (1) the complete; and (2) the incomplete, or meniscoid, type (Fig. 2). The former comprised 97.4 per cent and the latter 2 6 per cent of the total number of disks studied. For all decades the thickness of the superior border ranged from 4 mm. to 14 mm. and that of the inferior border from 1 mm. to 10 mm.

The intensity of the degenerative, regressive changes in the disks for the first three decades ranged to 2 plus zero. Gross inspection of one disk showed evidence of abnormal thinning, shredding and lamination of its fibers. In one instance the articular surfaces of the clavicles and the sterna of the joints of the third decade revealed definite evidence of degenerative alterations in the form of thinning, fibrillation and fraying of the lining fibrocartilage (Fig. 3, *top*). The intensity was not severe, but this finding was evidence that regressive changes are at work in the sternoclavicular joint in some individuals as early as the third decade. During the next three decades the intensity of the altera-

FIG. 2. (*Top*) Right sternoclavicular and acromioclavicular joints of a male 40 years of age Note that the articular disk of the sternoclavicular joint is meniscoid in shape and permits the two compartments to communicate with each other. This appears to be a congenital variation and not the result of degenerative changes. Observe the advanced changes implicating the articular surface of the clavicle and the sternum. This joint shows the most severe alterations encountered in this decade.

Note the advanced changes in the acromioclavicular surfaces They present a granular appearance. Also, marginal and surface excrescences are demonstrable. The disk is hypertrophied markedly.

(*Bottom*) Right sternoclavicular and acromioclavicular joints of a female 37 years of age. Note that the articular surfaces of the clavicle and the sternum show no gross alterations

(DePalma, A. F.: Degenerative Changes in the Sternoclavicular and Acromioclavicular Joints in Various Decades, Springfield, Ill., Thomas)

tions in the intra-articular disks rose very slowly but was not severe It was not until the seventh decade was reached that severe, over-all implication of the disks was noted The abnormalities comprised perforation or complete deterioration of the structures (Fig. 3, *bottom*). The first perforated disk was observed in the fourth decade, however, all other disks of this age period were intact (Fig 4, *top*). In the fifth decade, all disks were intact except one. Three perforated disks were encountered in the sixth decade and 8 in the seventh decade Thirteen of the 25 disks in the seventh decade exhibited advanced regressive changes (Fig. 4, *bottom*). In the eighth decade, 6 disks were

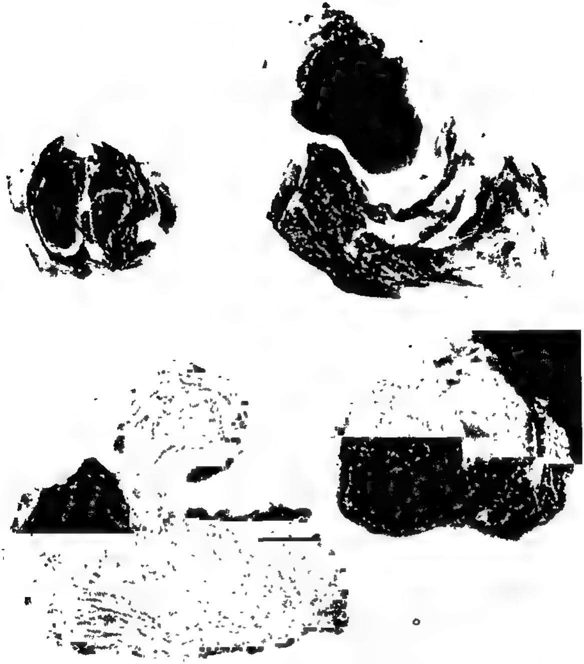


FIG. 3. (*Top*) Right sternoclavicular and acromioclavicular joints of a male 26 years of age Note the furrowing, fraying and irregularity of the articular surface of the clavicle. The disk is a stout structure, but its surfaces also exhibit shredding and lamination, particularly at its center. The acromioclavicular joint exhibits more advanced changes than the sternoclavicular. Observe the severe alterations in the articular surface of the clavicle, whose cartilage is frayed and pitted The articular disk is meniscoid in shape and shows severe regressive changes. (*Bottom*) Left sternoclavicular and acromioclavicular joints of the individual whose right joints are depicted in Figure 2 (*top*) Observe that the articular disk of the sternoclavicular joint is not a complete structure and resembles in shape the disk of the right joint. (DePalma, A F. Degenerative Changes in the Sternoclavicular and Acromioclavicular Joints in Various Decades, Springfield, Ill., Thomas)

perforated, and in the ninth and the tenth decades 7 disks were perforated (Fig. 5, *top*). These changes revealed that although some disks, as early as the fifth decade, showed severe alterations in the form of perforations, the incidence was rather low, and it was not until after the seventh decade that the incidence rose to a high level.

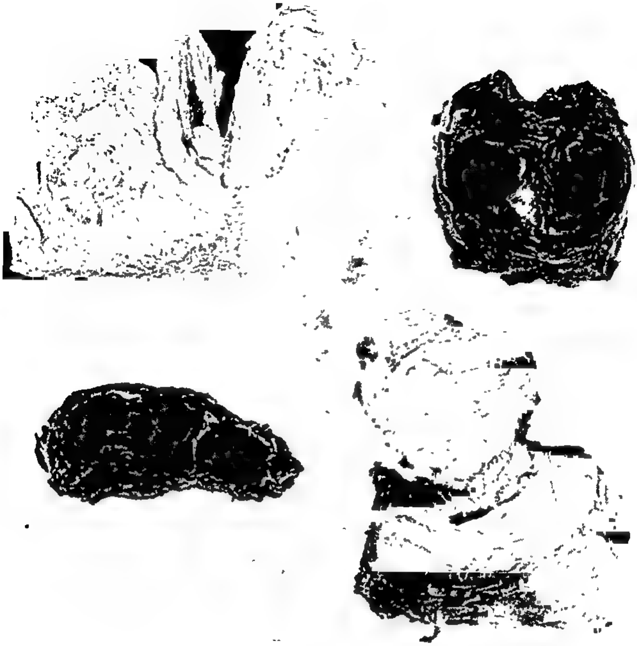


FIG. 4. (*Top*) Left sternoclavicular and acromioclavicular joints of a male 37 years of age. The articular disk of the sternoclavicular joint exhibits fraying, thinning, lamination and an irregular central perforation The articular surfaces of the acromioclavicular joint reveal minimal regressive changes. Observe the meniscoid configuration of the degenerated articular disk. (*Bottom*) Observe total disintegration of the disk of the sternoclavicular joint The articular surfaces exhibit severe degenerative changes. (Female, 63 years of age) (DePalma, A F Degenerative Changes in the Sternoclavicular and Acromioclavicular Joints in Various Decades, Springfield, Ill., Thomas)

Study of the corresponding articular surfaces of the clavicles and the sterna of the joints in the various decades disclosed that the alterations in the disks paralleled, in a measure, those in the articular surfaces of the bony components It became apparent that so long as the disks remained sturdy, intact structures, they were capable of meeting the functional demands of the articulations and of protecting adequately the articu-

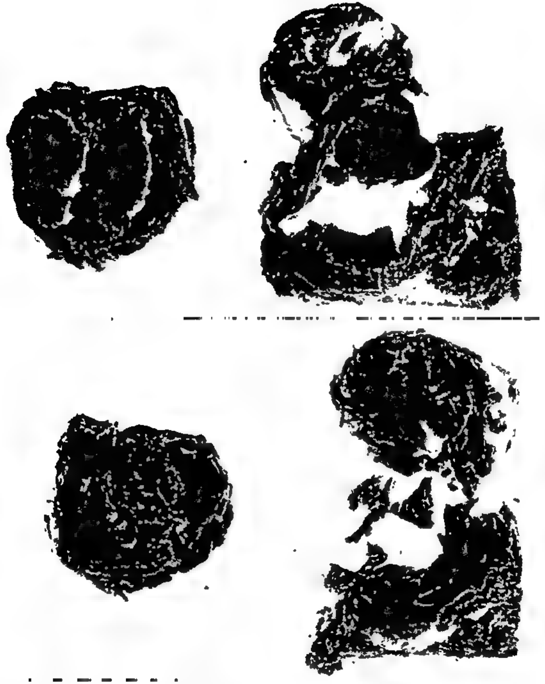


FIG. 5. (*Top*) Right joints of a female 78 years of age. Note that only a circular tab of the disk remains The surfaces of the sternoclavicular joint show severe degenerative changes The acromioclavicular joint shows advanced degenerative changes. The articular disk has the configuration of a meniscus. (*Bottom*) Right joints of a female 84 years of age. The sternoclavicular joint shows widespread involvement, the disk exhibits a central perforation. (DePalma, A F.: Degenerative Changes in the Sternoclavicular and Acromioclavicular Joints in Various Decades, Springfield, Ill, Thomas)

lar surfaces of the sterna and the clavicles. The disk was able to perform this function without any difficulty in the greater majority of the individuals up to the seventh decade. However, at this point in most instances the disks were no longer able to meet the functional demands made upon them; hence severe degenerative alterations were evident. It became apparent that once the protective mechanism of the disk was lost, the articular

FIG. 6. Right joints obtained from a male 94 years of age. The articular surfaces of the sternoclavicular joint disclose less impairment than the articular surfaces of the remaining joints of the ninth and the tenth decades. The articular disk exhibits minimal changes. The disk of the acromioclavicular joint is a complete structure dividing the joint into two separate compartments. (DePalma, A. F.: Degenerative Changes in the Sternoclavicular and Acromioclavicular Joints in Various Decades, Springfield, Ill, Thomas)

surfaces underwent rapid deterioration. Now the articular surfaces received directly all stimuli of stresses associated with function. The buffer effect of the disk was lost, and the conditions necessary for efficient nutrition of the articular surfaces of the sternum and the clavicle were impaired (Figs. 4, *bottom*, and 5).

OBSERVATIONS NOTED RELATIVE TO THE INTRA-ARTICULAR DISKS OF THE ACROMIOCLAVICULAR JOINTS

Study of the specimens of the first decade revealed that the full level of development of this articulation progressed more slowly than that of the sternoclavicular joint. In all the acromioclavicular joints of the premature infant, a flexible band of fibrocartilage was continuous with the adjacent cartilage of the acromion and the clavicle In the first decade, no joint cavity was demonstrable in specimens of 12, 16 or 23 months of age. A joint cavity was first demonstrable in this series in the acromioclavicular joint of a child 3½ years of age. Two types of disks were encountered—a complete disk and a meniscoid, or incomplete, disk (Fig. 3-6). However, it was impossible to determine the incidence of these types because of the rapid deterioration of the structures after the second decade. But all the disks of the second decade were meniscoid in form; even at this early age the inner margin of the structures showed some fraying and scalloping. The meniscoid variety resembled closely the meniscus of the knee joint, whereas the complete disk divided the joint cavity into two separate compartments. In this entire series, only 8.6 per cent of the acromioclavicular joints demonstrated a complete intra-articular disk. In 81.1 per cent, either the structure was absent or only remnants of the disk were discernible; 10.3 per cent disclosed a meniscoid type of disk, and in each instance it was impossible to determine whether the meniscoid disk was congenital

in origin or the result of degenerative changes attributable to the secondary degenerative changes that had occurred. Whereas the disks of the sternoclavicular joints of the second decade disclosed no evidence of degenerative abnormalities, the disks of the acromioclavicular joints of the same decade showed definite evidence of degenerative alterations. In all joints of the subsequent decades, marked degenerative lesions of the disks were encountered. As previously noted, in 81.1 per cent of all the joints of this series, the disks were either absent or in the form of irregular tabs and remnants; a high level of involvement was noted as early as the fourth decade. Only one specimen in this decade presented a complete intra-articular structure; the remaining disks in this age period had disintegrated completely. It was interesting to note that moderate changes in the acromioclavicular surfaces of the bony elements were noted as early as the fourth decade, and these increased in severity from decade to decade. The changes comprised erosion, fibrillation and lamination of the articular cartilage of the acromion and the clavicle and the formation of marginal osteophytes and surface excrescences producing severe incongruity of the articular surfaces (Fig. 2, *top*). Marginal osteophytes and surface excrescences also were responsible for enlargement of the bony components of the joint. These alterations were also noted in the later decade in the sternoclavicular joint; however, they were not present until the very late decades of life, whereas in the acromioclavicular joint they were noted as early as the fourth decade. It soon became apparent that the early and extensive alterations and disintegration of the disks of the acromioclavicular joints were responsible for the changes that occurred in the articular surfaces of the acromions and the clavicles. With the loss of this important intra-articular structure, the acromioclavicular joint underwent rapid and severe degeneration (Figs. 4 and 5, *top*).

DISCUSSION

In order to appreciate the role of the intra-articular disks of the sternoclavicular and the acromioclavicular joints, comprehension of the anatomy and the functional mechanism of these joints is essential.

The Sternoclavicular Joint

The sternoclavicular articulation is formed by the articular surface of the sternal head of the clavicle, the clavicular incisura of the sternum and the cartilage of the first rib. The intra-articular disk divides this articulation, except in a few instances, into two separate compartments — the discosternal and the discoclavicular compartments. The ends of the clavicle and the sternum show considerable incongruity. However, nature has compensated for this lack of congruence by interposing between the articular surfaces a stout fibrocartilaginous disk whose internal structural arrangement makes it an effective buffer to strains and stresses incident to function. The sternal head of the clavicle is, roughly, prismatic in configuration and is covered by fibrocartilage. The head of the clavicle is larger than the articular surface of the sternum, so that it protrudes not a little beyond the sternal margin. The articular surface of the sternum presents a celliform configuration, and it is perpendicular to the head of the clavicle. It, too, is covered by fibrocartilage of varying thicknesses.

As previously noted, the intra-articular disk is convex-concave in configuration, its circumference is slightly thicker than its center, and its superior portion is thicker than the inferior. There is considerable variation in the size of the structure in the various decades; in general, it is thicker in the fifth, the sixth and the seventh decades than it is in the previous age periods. In the late decades, many disks exhibit pronounced regressive alterations. The disk is attached to the upper and posterior aspect of the articular surface of the clavicle by a broad, roughly circular, area, and below it fuses with the

cartilage of the first rib at its junction with the sternum. Its circumference is attached to the joint capsule, which is far from being taut in spite of the reinforcement it receives from the anterior and the posterior sternoclavicular ligaments and the interclavicular ligaments. In the adult joint, the intra-articular disk exhibits a characteristic internal structure. It comprises stout, strong, sinewy fibers of connective tissue that are intertwined completely. Interspaced among these fibers are fusiform cells and true cartilage cells. In the center of the disk, the fibers are more matted together, and the cellular elements are reduced in number. This particular design makes it possible for this intra-articular structure to meet the great functional demands made upon it.

Finally, the stability of the sternoclavicular joint depends in a large measure on the integrity of the costoclavicular ligament. This ligament is a short, flat, strong structure, rhomboid in shape. It consists of two layers of fibers that arise from the upper and medial portion of the cartilage of the first rib and run obliquely upward, lateralward and backward to insert into the costal tuberosity on the undersurface of the inner portion of the clavicle. Its function principally is to oppose the pull of the sternocleidomastoid muscle on the clavicle and prevent lateral and upward displacement of the sternal end of the clavicle. In addition, it acts as a pivot during forward and backward motion and during elevation and depression of the shoulder. This articulation is the only link between the trunk and the shoulder girdle, and is the focus from which all movements of the shoulder girdle originate.

It was pointed out by Fick, Mollier and Rouvière that this joint was the most frequently moved articulation in the body. Every motion in the upper extremity is accompanied by some form of motion in the sternoclavicular joint in the form of rotation, impact or glide. It becomes apparent that the anatomic composition of this articulation must be such that it is capable of an extraordinary range of motion. This requisite is met by the interposition of a stout intra-articular disk between the articulating surfaces of the clavicle and the sternum dividing the articulation into two compartments.

Analysis of the movements of this articulation reveals that it moves about three axes. Forward and backward movement of the clavicle occurs about a perpendicular axis; upward and downward movement is performed about a sagittal axis; and longitudinal rotation or circumduction of the clavicle is executed about its length axis. The excursion of the range of the clavicle about the sagittal axis is approximately 30°. The clavicle rises 55° above the horizontal during upward motion of the shoulder and descends 5° below the horizontal during downward motion. The center of rotation of this movement passes through the costoclavicular ligament that lies outside the joint and lateral to it.

In forward and backward movement about the perpendicular axis, the clavicle moves approximately 30° in each direction. Free rotation of the clavicle about its longitudinal axis is possible in mid-positions of the two aforementioned movements. The amplitude of this rotating movement is approximately 30° in each direction; hence the clavicle describes in its movement an angular cone with a radius of action of 60°. The sternoclavicular and the acromioclavicular joints are closely related in the over-all mechanism of the shoulder girdle. As the sternal end of the clavicle moves in one direction, the acromial end moves in the opposite direction. The costoclavicular ligament, which lies between the two articulations, is the point through which the center of the axis of motion passes.

The observations noted in this investigation provide unequivocal evidence that the sternoclavicular joint is so constructed that it can meet all the demands made upon it by a prehensile extremity. This investigation discloses further that the most important component of the articulation is the stout intra-articular fibrocartilaginous disk. This

structure is of sufficient size and is so constructed that it acts as an adequate buffer between the articular surfaces of the clavicle and the sternum, thereby minimizing the deleterious, noxious agents of the stress and strain incident to function and preventing early degenerative changes of the bony and cartilaginous elements of the joint. It has been clearly shown that so long as the integrity of this disk is maintained, the over-all recessive changes in the other joint components are only minimal in degree. This is even true in the very late decades of life—the seventh, the eighth, the ninth and the tenth—when the intra-articular fibrocartilage begins to show gross evidence of disintegration. These observations afford an explanation of the infrequent implication of this joint as a source of pain and dysfunction noted clinically.

The Acromioclavicular Joint

The acromioclavicular joint is formed by the acromial end of the clavicle and the medial margin of the acromion. The ends of both these bones are covered by hyaline cartilage. The articular surfaces exhibit pronounced incongruity. In the first decade of life, a small, thin fibrocartilaginous disk is found in all instances. This may be of two types—a complete disk or a meniscoid type disk. However, as previously noted, this disk undergoes rapid deterioration, first demonstrable in the second decade, so that for all practical purposes the joint has no intra-articular disk to protect the articular surfaces after the fourth decade. The ends of the bone comprising this articulation are surrounded completely by a weak, relaxed capsule that is reinforced above by the superior acromioclavicular ligament and below by the inferior acromioclavicular ligament. The former is the stronger structure. The integrity of this joint is dependent upon the superior acromioclavicular ligament and the insertion of the deltoid and the trapezius muscles into the clavicle and the acromion, and not on the coracoclavicular ligament. This observation was first noted by Urist.

The coracoclavicular ligament comprises two fasciculi—the trapezoid and the conoid ligaments. It spans the interval between the clavicle and the coracoid of the scapula, binding one to the other. Both segments run from above downward and medially. The trapezoid fasciculus is thin and quadrilateral. It is attached above to the trapezoid line on the undersurface of the clavicle and below to the upper surface of the coracoid process. This segment lies anterior and lateral to the conoid segment. The conoid fasciculus consists of a dense, conical band of fibers, with its base directed upward, which is attached to the coracoid tuberosity on the undersurface of the clavicle. Its apex is attached to the base of the coracoid process medial to the trapezoid fasciculus. The lateral border of this segment blends with the posterior border of the trapezoid segment, forming an angle projecting backward. It is significant that the coracoclavicular ligament is attached to the clavicle, where it curves posteriorly on its outer third. During elevation of the arm outward, rotation of the scapula displaces the coracoid process downward. In turn, the ligament, by virtue of its attachment, pulls on the posterior curvature, causing the clavicle to rotate in its longitudinal axis. As pointed out by Inman, Saunders and Abbott, in effect this cranklike action of the clavicle produces an elongation of the ligament, permitting unrestricted abduction of the arm.

As in the sternoclavicular joint, the acromioclavicular joint is capable of motion in three planes. Forward and backward movement takes place about a vertical axis; upward and downward movement, about a sagittal axis. Rotating movement occurs between the clavicle and the scapula during elevation of the arm. All movements are gliding and shearing whose center lies outside the articulation. During the upward and backward movement, the scapula describes an arc of 60° to 70°. Forward movement

is checked by abutment of the acromion against the clavicle; backward movement, by the trapezoid ligament. The field of excursion in the upward and downward movement is exceedingly small. The acromioclavicular joint contributes 20° to the total range of elevation of the arm.

It is apparent from the anatomic description of the bone ends, which are small and incongruous, that for all practical purposes all movements that take place at this joint are shearing in nature. The intra-articular disk, being a feeble and poorly constructed structure, is a very poor buffer for this joint and fails to protect the articular surfaces. This has been clearly demonstrated in the specimens studied in this investigation. It becomes apparent that (1) because the intra-articular disk fails to protect the articular surfaces of the acromioclavicular joint and (2) because the resulting degenerative changes are in most instances pronounced, this joint frequently is the seat of painful disorders in more cases than is generally realized.

CONCLUSIONS

A gross study of the sternoclavicular and the acromioclavicular joints in various decades has been presented. The following observations have been recorded:

1. Specimens of the first decade exhibited different levels of development of the sternoclavicular joints in different individuals, and, as noted by Langen, complete development is not achieved until the latter years of the third decade. Two developmental types of disks are encountered: (1) the meniscoid; and (2) the complete form.

2. Regressive changes in the components of the sternoclavicular joints are first manifested in the third decade. They progress slowly in intensity and are not severe in any decennium until the seventh and the eighth decades are reached.

3. Protection of the articular surfaces of the sternoclavicular joints is provided by the intra-articular fibrocartilaginous disk, which is capable of resisting attritional changes and does not show widespread impairment until the seventh and the eighth decades are reached.

4. With disintegration of the disks, extensive involvement of the articular surfaces of the sternoclavicular joints ensues.

5. The acromioclavicular joints in the early years of the first decade lag behind the sternoclavicular joints in development. In the later years, complete development is achieved. In the second decade, the acromioclavicular joints begin to exhibit degenerative abnormalities, first observed in the intra-articular disks.

6. Two types of developmental disks are encountered: (1) the meniscoid; and (2) the complete variety.

7. Rapid deterioration of the acromioclavicular disks is reflected in the articular surfaces of the joint. These undergo rapid and severe disintegration, reaching a high level of impairment in the fourth decade.

BIBLIOGRAPHY

Fick, R.: Handbuch der Anatomie und Mechanik der Gelenke, Jena, Fischer, 1911.

Inman, V. T., Saunders, J. [redacted] de C. M., and Abbott, L. C.: Observations on the shoulder joint, J. Bone & Joint Surg. 26:1-30, 1944.

Langen, P.: Untersuchungen über die Altersveränderungen und Abnutzungserscheinungen am Sternoclaviculargelenk, Virchows Arch path. Anat. 293:381-408, 1934.

Urist, M. R.: Complete dislocations of the acromioclavicular joint, J. Bone & Joint Surg. 28: 813, 1946.

Le Rolo del Discos del Articulationes Sternoclavicular e Acromioclavicular

Summario in Interlingua

Un studio macroscopic del articulationes sterno- e acromioclavicular a varie etates es presentate, incluse le sequente observationes.

1. Specimens ab subjectos in le prime decennio de lor vita exhibiva differente nivellos de disveloppamento del articulation sternoclavicular. Como Langen lo notava, le disveloppamento non es complete usque verso le fin del tertie decennio. Es incontrate discos de duo typos disveloppamental: (1) le forma meniscoide e (2) le forma complete.

2. Alterationes regressive in le componentes del articulationes sternoclavicular comencia manifestar se in le tertie decennio. Illos progrede lentemente in intensitate e non deveni sever usque al septime e octave decennio.

3. Le superficie articular del articulation sternoclavicular es protegite per le disco cartilaginose intra-articular. Iste disco es capace de resister contra le effectos de attrition e non exhibi extense grados de damnification ante le septime o le octave decennio.

4. Quando le disco se disintegra, le superficies articular del articulation sternoclavicular es extensemente compromittite.

5. In le prime annos del prime decennio, le articulation acromioclavicular se disveloppa plus lentemente que le articulation sternoclavicular. In le curso del annos subsequente del prime decennio, le disveloppamento de iste articulation es completate. Durante le secunde decennio, le articulation acromioclavicular comencia exhibir anormalitates degeneratori. Istos es primo observate in le discos intra-articular.

6. Es incontrate duo typos disveloppamental de disco acromioclavicular: (1) le forma meniscoide e (2) le forma complete.

7. Le deterioration rapide del disco acromioclavicular es reflectite in le superficies articular. Istos exhibi un disintegration rapide e sever que attinge un alte nivello de damnification durante le quarte decennio.

21

Hodgkin's Disease of Bone*

George S. Phalen, M.D.†

In 1832, Dr. Thomas Hodgkin described 7 cases of a peculiar affection of the reticuloendothelial system with generalized lymphadenopathy and splenomegaly. Since then the disease has been known by his name, and the protean manifestations of Hodgkin's disease have been described in hundreds of published reports. The exact nature and etiopathogenesis of Hodgkin's disease are not yet fully understood, but Sternberg,[12] in 1898, and Reed,[10] in 1902, described the typical histologic evidence by which the disease still is recognized today.

Since Hodgkin's disease affects the reticuloendothelial system, frequently involvement of the bone marrow occurs at some time in the course of the disease. Benda (1904) is credited with being the first to describe osseous involvement. The bone may become affected by direct invasion from an adjacent granulomatous lesion, such as a matted mass of lymph nodes. Small granulomatous emboli may lodge in the bone marrow too, producing a metastatic lesion by the hematogenous route. Falconer and Leonard[4] have advanced the hypothesis that osseous lesions in Hodgkin's disease may be produced by the transfer of some unknown agent that is capable of initiating a focus of the disease *in situ*. No experimental evidence has been produced to substantiate this theory

Often, involvement of the bone marrow may be demonstrated only after careful histologic study of the bones at necropsy. Frequently, however, the bone involvement may be of such magnitude as to be apparent on roentgenograms. The roentgenographic appearance of Hodgkin's disease never is pathognomonic. Most often, the skeletal lesions are osteolytic, but some are osteoplastic or proliferative. Periosteal or infiltrative lesions rarely are seen alone or in conjunction with medullary lesions. Combinations of these different types of bone involvement may be seen in a single lesion

CLINICAL FEATURES

The clinical features of Hodgkin's disease in bone can best be illustrated by the following typical case histories of patients seen at the Cleveland Clinic.

Case 1. A housewife, 22 years old, was first examined on January 28, 1957. Her chief complaint was pain of 2 months' duration in the left lower back and in the posterior region of the left hip. She stated that she had had no previous trouble with the hip until November 26, 1956, when she "felt something snap" in her back while she was bowling. An osteopath told her, "Something is out of place," and he prescribed manipulations, which gave some relief for several weeks Then, after lifting a heavy object, pain in the lower back and the left hip recurred and forced her to limp on the left leg There was no previous history of tuberculosis or other illness.

A general physical examination revealed a few small shotty glands in the posterior cervical region bilaterally and also in the left axilla Re- [illegible] Ortho- [illegible] patient [illegible] higher

* Read at the meeting of The Pan-Pacific Surgical Association held in Hawaii, November, 1957.

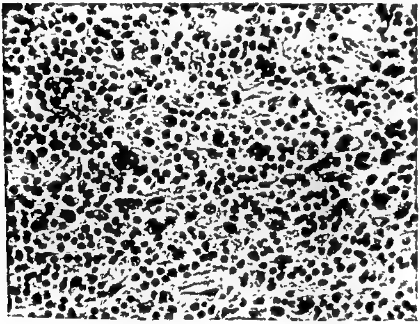
† Department of Orthopedic Surgery, The Cleveland Clinic Foundation, and the Frank E. Bunts Educational Institute, Cleveland, Ohio.

than the left. All back motions were greatly restricted. There was moderate tenderness over the left sacro-iliac area.

Results of laboratory tests, including a routine urinalysis, blood count, blood sugar and serology determinations, were within normal limits. A sedimentation rate of the blood and a Bence Jones protein determination in the urine were negative. A roentgenogram of the chest showed no abnormality, but roentgenograms of the spine and of the pelvis showed an extensive lytic lesion involving the bones adjacent to the left sacro-iliac joint (Fig. 1).

The patient was hospitalized on February 21, 1957, for biopsy of the lytic lesion. A window was cut in the cortex of the posterior ilium, exposing a fleshy, grayish-red friable mass of tissue. A large portion of the mass was curetted out, and a block of cortical bone, removed from the posterior ilium, was wedged across the defect. Routine cultures, including a culture for the tubercle bacillus, were sterile. Microscopic examination of the fleshy portions of the excised specimen showed atypical reticulum cells with frequent mitoses and occasional Reed-Sternberg cells (giant polynuclear cells with prominent nucleoli). Sections of bony fragments showed a more inflammatory condition with foci of histiocytes, plasma cells, lymphocytes, eosinophils and Reed-Sternberg cells (Fig 2).

Roentgen therapy was instituted, and the patient received a total of 2,500 r over the left sacro-iliac area The pain subsided rapidly with this treatment, and the patient was discharged



FIGS. 1-3, Case 1. Fig. 1 (*Top*). Roentgenogram of pelvis. There is an extensive lytic lesion involving bones adjacent to the left sacro-iliac joint.

FIG. 2 (*Center*). Photomicrograph of specimen removed from region of the sacro-iliac joint. There is a pleomorphic cellular pattern consisting of plasma cells, lymphocytes, macrophages, abnormal reticulum cells and a rare Reed-Sternberg cell.

FIG. 3 (*Bottom*). Roentgenogram of pelvis 6 months after curettement of lytic lesion seen in Figure 1. An iliac bone graft was placed across the sacro-iliac joint because the initial fresh frozen tissue diagnosis was "chronic inflammation."

FIG. 4. Case 2. Lateral roentgenogram of cervical spine. There is extensive destruction of the body of C-7 and increased density of the body of C-6. The spinal cord was compressed by neoplastic tissue arising apparently from these vertebrae. Pathologic examination revealed typical Hodgkin's disease.

FIG 5. Case 3. Roentgenogram of left hip showing lytic lesion involving the lesser trochanter and the medial cortex of the proximal third of the femur.

from the hospital on March 8, 1957. She was advised to wear a lightweight corset.

On August 26, 1957, at follow-up examination, she had no pain in the back or the legs. She no longer needed to wear the corset. She stated that she recently had had a fever that lasted about 4 days, but there was no evidence of respiratory infection. A roentgenogram of the chest revealed no abnormality. A roentgenogram of the pelvis showed evidence of some sclerosis about the operative site in the ilium; the bone graft across the sacro-iliac joint seemed to be healing well (Fig. 3).

Case 2. A married woman, 23 years old, was first examined on December 10, 1945. Her chief complaint was of swellings on either side of the neck, which had been present for 1 month. Examination revealed bilateral cervical adenopathy and large left supraclavicular nodes. A roentgenogram of the chest showed a dense oval mass in the region of the upper mediastinum. Biopsy and pathologic evaluation of a cervical node confirmed the diagnosis of Hodgkin's granuloma. Roentgen therapy was instituted, and the patient improved

On May 22, 1946, the patient returned, stating that in the past 6 weeks she had noticed gradually increasing stiffness and pain in the neck and across both shoulders. Roentgenograms of the cervical spine showed some erosion of the body of C-7. Roentgen therapy was resumed, and the patient got along well until October, 1947, when she returned because of generalized pruritis, fatigue, weakness and bouts of fever. She had no special complaints referable to the neck and the shoulders She was given a course of nitrogen mustard, administered intravenously.

In February, 1948, there was recurrence of pain in the neck. A cervical collar was applied, and roentgen therapy again was instituted. Within 2 months the neck pain disappeared, and the patient was able to discard the cervical collar.

In January, 1949, she returned because of definite weakness of the right lower extremity with a sensory level at the second thoracic dermatome. A myelogram revealed a block at the level of T-1. A roentgenogram of the cervical spine showed extensive destruction of the body of C-7 and increased density of the body of C-6 (Fig 4). A laminectomy of C-6, C-7 and T-1 was performed on January 20, 1949, with partial removal of a firm, rubbery, soft-tissue neoplastic mass lying anterior to the spinal cord and compressing the cord at that level. A plaster cast was applied, encasing the posterior head, the

neck and the thorax. A cord bladder and further paralysis of the lower extremities developed. The patient died on October 9, 1949, nearly 4 years after the onset of Hodgkin's disease.

Case 3. A Negro housewife, 40 years old, was first examined on July 30, 1957. She first noticed some numbness and weakness in the left thigh in February, 1957. A month later she noted a constant deep pain in the upper third of the left thigh, which became steadily worse. For the past 3 weeks she had been confined to bed or a wheel chair because of pain in the left hip on bearing weight.

On examination, the left leg was held in external rotation, and all movements of the left hip were painful. There was no palpable mass about the left hip, but there was a firm, nontender gland in the left groin. No other lymphadenopathy was present. Roentgenograms of the chest and the lumbar spine revealed no abnormality. A roentgenogram of the left hip revealed a lytic lesion involving the proximal portion of the shaft and the lesser trochanter with erosion of the cortex (Fig. 5).

Pathologic examination of a biopsy specimen of the left inguinal node revealed Hodgkin's granuloma, apparently arising in a giant follicular lymphoma. A needle biopsy specimen of the femur showed only fibrosis of the marrow.

After a course of cobalt-60* teletherapy (total 2,500 r), pain disappeared from the left hip, and an almost normal range of motion returned to this joint. The patient was released from the hospital, ambulatory on crutches, with partial weight-bearing on the left leg. Six weeks later a roentgenogram showed complete recalcification of lytic area in the femur.

Case 4. A farmer, 54 years old, was admitted to the hospital on May 9, 1946, for emergency treatment of acute low-back pain and right sciatica. In November, 1945, he had undergone a laparotomy for intestinal obstruction due to adhesions; his convalescence was uneventful. Five weeks postoperatively he first noticed gradual onset of pain in the lower back, radiating down the posterior aspect of both lower extremities to the ankles. The sciatic pain disappeared gradually from the left leg but became more intense on the right side in the past month.

On physical examination there was marked tenderness to the right of the L-4 spinous process. All motions of the back were restricted and painful. The knee and the ankle reflexes were normal. There was some hypesthesia along the lateral aspect of the right lower leg, extending onto the lateral aspect of the foot. There was a moderately enlarged, nontender, firm lymph node in the right supraclavicular region, and a similar gland was palpable in the right axilla.

A roentgenogram of the chest revealed no abnormality. A roentgenogram of the lumbar spine showed all the interspaces to be well preserved, but there was partial collapse of the body of L-5 with evidence of a lytic lesion involving the central portion of the body of this vertebra.

The enlarged node in the right axilla was excised, and pathologic examination revealed Hodgkin's sarcoma. The patient was given roentgen therapy (a total of 2,600 r) over the lower lumbar spine. Pain in the back was not relieved significantly. He was released from the hospital on June 11, 1946, and remained at home almost completely bedfast until his death on January 3, 1947.

Case 5. An insurance salesman, 45 years old, was examined in January, 1947, because of pain in the posterior lower left side of the chest. Six months earlier he had had an attack of acute low-back pain with radiation into the posterior aspect of both thighs. Shortly after this an intermittent pain of a pleuritic nature developed in the lower left side of the chest.

Physical examination revealed no lymphadenopathy. There was moderate tenderness over the left eighth rib posteriorly. Examination of the spine revealed no abnormality. A roentgenogram of the lumbar spine showed no evidence of abnormality, but one of the chest revealed an expanding destructive lesion of the left eighth rib posteriorly (Fig. 6, *top, left*).

The involved portion of the eighth rib was excised completely, and pathologic examination revealed Hodgkin's granuloma. Four months later there was evidence of enlarged glands in both axillae and both groins, and a biopsy specimen of a right inguinal and a left axillary node revealed Hodgkin's granuloma. At this time a roentgenogram of the lumbar spine showed an osteoplastic lesion in L-4 and L-5 with preservation of the intervertebral spaces (Fig. 6, *top, right*)

Despite extensive roentgen therapy, 2 months later both osteoplastic and osteolytic involvement of the left sacro-iliac region and the first sacral segment was apparent on a roentgenogram of the pelvis (Fig. 6, *bottom, left*). Roentgen therapy was continued.

* The radioactive material used was supplied by Oakridge National Laboratory on authorization of the Isotopes Division, United States Atomic Energy Commission, Oak Ridge, Tenn

FIG. 6 Case 5. (*Top, left*) Roentgenogram of chest. There is an expanding destructive lesion of the left eighth rib posteriorly (*Top, right*) Roentgenogram of lower lumbar spine, lateral view. The bodies of L-4 and L-5 show osteoplastic lesions with fairly good preservation of the intervertebral disks. (*Bottom, left*) Roentgenogram of pelvis. Despite extensive roentgen therapy, there developed both osteoplastic and osteolytic involvement of left sacro-iliac region and first sacral segment. (*Bottom, right*) Lateral roentgenogram of the lower dorsal and the upper lumbar spine showing collapse of T-11, T-12 and L-1 There was associated cord compression.

By July, 1948, the patient had improved considerably, although he still had some pain in the back. During the next 4 years, he received 3 courses of nitrogen mustard, administered intravenously. From 1950 to 1952 he received 6 doses of P^{32}* (radioactive phosphorus). [illegible] ... [illegible] lymphedema of the right leg, believed to be due to destruction of deep and superficial lymphatic structures by roentgen therapy.

At the time of his last hospitalization, in September, 1952, there was complete paralysis of both lower extremities and a cord bladder due to spinal cord compression associated with osteoblastic collapse of the eleventh and the twelfth thoracic and the first lumbar vertebrae (Fig. 6, *bottom, right*). A course of triethylene melamine (TEM) was given, and the patient was released to his home for terminal care. He died in September, 1953, almost 7 years after the onset of Hodgkin's disease.

DIAGNOSIS

Hodgkin's disease of bone may be confused with Ewing's tumor, reticulum-cell sarcoma, osteogenic sarcoma, leukemic involvement of bone, osteomyelitis, eosinophilic granuloma and metastatic carcinoma in bone. All these bone affections, with the possible exception of metastatic carcinoma, show some characteristic roentgenographic appearance. Ewing's sarcoma may show an "onionskin" layering of the periosteum and often an overlying soft-tissue mass. Ewing's tumor generally involves the diaphysis; it may spread to the metaphysis but does not invade the epiphyseal plate.

Osteogenic sarcoma usually starts in the metaphysis and invades the epiphyseal plate. New reactive bone may be deposited perpendicularly to the shaft, giving the characteristic "sunburst" appearance. In leukemic involvement of bone, one of the most common findings is elevation of the periosteum with new bone formation along the shafts of long bones, although osteolytic changes predominate elsewhere.

* The radioactive material was supplied by Oak Ridge National Laboratory on authorization of the Isotopes Division, United States Atomic Energy Commission, Oak Ridge, Tenn

FIG. 7. Osteoplastic lesion of Hodgkin's disease involving the middle third of the humeral shaft. This 34-year-old woman had had multiple bone lesions for 10 years.

In osteomyelitis, sequestra commonly are found, and usually there is much periosteal new bone formation. Eosinophilic granuloma is purely osteolytic in nature; a soft-tissue mass often is found over the bone lesion; and pathologic fractures are common when the lesion is in the shaft of a long bone.

The Hodgkin lesion in bone most often is purely destructive or osteolytic, with destruction of the cortex and expansion of the shaft. In the spine, the vertebral bodies themselves most often are involved: frequently the bodies collapse, and the intervertebral disks are spared[7] (Fig. 6, *top, right*). Proliferative or osteoplastic lesions may also occur (Fig. 7), and, when these are present in the lumbar spine or the pelvis, the roentgen appearance is very similar to that of metastases of prostatic carcinoma (Fig. 8). A combination of osteolytic and osteoplastic lesions is not uncommon in a single bone (Fig. 6, *bottom, left*). Periosteal new bone

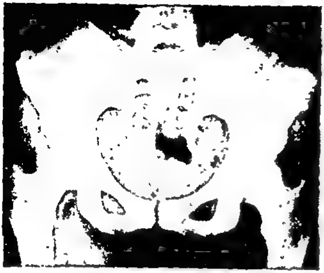


Fig. 9. [illegible]
[illegible]
[illegible]
genographic appearance resembles very closely that of metastatic carcinoma of the prostate.

formation may exist alone or in combination with a medullary lesion. Usually the ends of long bones are involved. Pathologic fractures have been reported,[3,6] but certainly they must be rare; there were no pathologic fractures in our series.

Although, generally, Hodgkin's disease is considered to be of primary interest to the internist and the radiotherapist, the orthopaedist always must consider this disease as a possibility in making a differential diagnosis of any destructive or proliferative bone lesion. When the diagnosis of Hodgkin's disease already has been established in a particular case, the orthopaedist naturally will assume that the bone lesion that he sees on roentgen examination is secondary to this disease. However, occasionally a patient with Hodgkin's disease will come directly to the orthopaedist for relief of pain in the back, the chest or the extremities. Lymphadenopathy or splenomegaly may be absent,[2,4,7,8] and it is reported[3] that amputation of an extremity has been performed on the assumption that a primary malignant bone tumor was present. Sciatic radiation of pain may occur with involvement of the lower lumbar spine, the sacro-iliac joint or the sacral plexus; and this may lead to the erroneous diagnosis of disk disease.

In Hodgkin's disease, as in all other destructive or infiltrative lesions of bone, the roentgenogram does not show the true extent of the bony involvement. Lesions of the marrow that do not involve the cortex of the bone will not be demonstrated roentgenographically. Of 30 cases showing gross metastatic involvement of the lumbar spine at necropsy, Young and Funk[14] found roentgen evidence of the bone lesions in only 13 cases. When a patient with Hodgkin's disease has unrelenting pain over a specific bony area, one must assume that the disease involves the bone, even though roentgenograms fail to reveal any definite bone lesion. These patients should not be denied the relief usually afforded by roentgen therapy until such time as the lesion becomes visible roentgenographically. When the diagnosis has not yet been established in a patient with bone pain, the orthopaedist may be forced to await the appearance of a bone lesion on the roentgenogram. Enlarged lymph glands elsewhere in the body or a widening of the mediastinal shadow in a roentgenogram of the chest may give a clue to the correct diagnosis.

Ultimately, the diagnosis of Hodgkin's disease must rest upon the pathologist's evaluation of a biopsy specimen either of a bone lesion or of a lymph gland. When there is no lymphadenopathy present, one is forced to do an open biopsy of the bone lesion. Needle biopsy may not obtain material that is satisfactory for microscopic study. There is no change in the blood that is characteristic, and marrow studies give little help in establishing the diagnosis.

TREATMENT

Roentgen therapy is the treatment of choice in Hodgkin's disease of bone, although the lesions in bone do not respond as well to irradiation as do the lesions in other sites. Pain in the bone usually is relieved quite promptly by irradiation, and in some

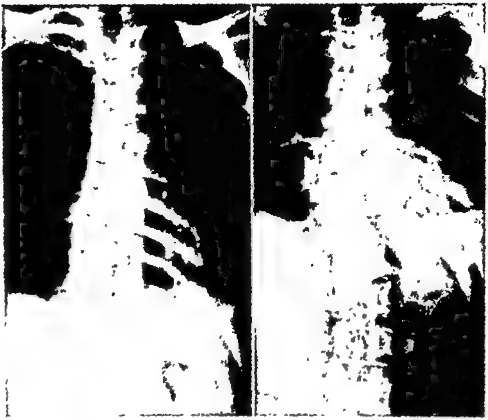


FIG. 9. (*Left*) Roentgenogram of dorsal and lumbar spine of a 38-year-old man with widespread bone involvement from Hodgkin's disease. Note especially the lytic involvement of the proximal ends of the tenth and the eleventh ribs on the left and almost complete destruction of the left twelfth rib. (*Right*) Two years later. There has been recalcification of the tenth, the eleventh and the twelfth ribs on the left.

cases there may even be evidence of some bone regeneration (Fig. 9). The usual roentgen dose to a single bone lesion varies from 2,000 to 2,500 r. When a patient with Hodgkin's disease complains of pain over a bone and the roentgenograms show no abnormality, usually it is advisable to proceed with roentgen therapy on a purely empiric basis, since there may be extensive bone involvement without changes being apparent roentgenographically.

When there is evidence of extensive systemic involvement, usually nitrogen mustard therapy is employed. Remissions often are produced in Hodgkin's disease by the intravenous injection of nitrogen mustard in the dose of 0.4 mg. per Kg. of body weight. Nitrogen mustard also is used when roentgen therapy fails, or further roentgen therapy may not be administered. Occasionally radioactive phosphorus may be of some therapeutic value. In using either nitrogen mustard or radioactive phosphorus, extreme care must be taken not to depress too greatly the function of the bone marrow.

Surgical removal of a bone lesion is seldom, if ever, advisable. Decompressive laminectomy occasionally may become necessary to relieve spinal cord compression. A back brace may aid the patient in becoming ambulatory and may delay the collapse of vertebral bodies at least until roentgen therapy may be administered.

DISCUSSION

The case reports serve to emphasize the various clinical manifestations of Hodgkin's disease of bone. Pain in the region of the affected bone is the primary complaint in almost every case. Usually the pain is severe, disabling and unrelenting in nature; it is essentially the same type of pain that occurs with malignant metastasis in bone. By the time that there is roentgenographic evidence of bone involvement, usually there is present some lymphadenopathy or splenomegaly to arouse suspicion of Hodgkin's disease or some allied disorder. Occasionally, though, as in Case 5, no lymphadenopathy may be present.

Bones may be involved quite extensively without causing pain; such lesions may be

discovered in skeletal roentgenographic surveys or in routine roentgenograms of the chest. Often, the ribs, the sternum, the skull and the pelvis may be the sites of symptomless infiltration by Hodgkin's granuloma. However, if the lesion is an expansile type, or if the lesion lies close to a joint, such as the sacro-iliac joint in cases with involvement of the ilium, pain always will be present. When the sacro-iliac joint is involved, as in Case 1, there usually will be referred pain down the posterior aspect of the ipsilateral lower extremity along the course of the sciatic nerve.

The incidence of bone lesions in Hodgkin's disease may vary widely, depending upon the investigator's method of study. When complete necropsies are performed and a careful search is made for lesions in the bone marrow, such lesions will be found in almost every instance.[11] During life, the incidence of osseous lesions will average about 10 per cent. However, this percentage may be increased considerably if frequent skeletal roentgenographic surveys are made in every case of Hodgkin's disease[9] In a recent review of 481 cases of Hodgkin's disease seen at the Cleveland Clinic from 1930 to 1957, there were 44 patients with demonstrable lesions in bone, this is an incidence of 9 per cent (table on this page).

Contrary to common belief, involvement of bone may occur early in the course of Hodgkin's disease. In our series of 44 cases, 25 patients had evidence of the disease 1 year or less prior to the diagnosis of the bone lesions. Only 11 patients had had the disease for more than 2 years.

Involvement of the bone in Hodgkin's disease certainly is much more common than is generally believed Some authors[11,13] believe that invariably there is involvement of bone marrow in Hodgkin's disease. When the infiltration of bone produces local symptoms or reveals its presence on roentgenograms, one usually is justified in assuming that the prognosis will be poor. In our series, 18 patients lived less than 2 years after a diagnosis of bone involvement was made; 11 lived less than 1 year; 3 lived more than 5 years. It is almost impossible to obtain accurate statistics on whether or not bone involvement in Hodgkin's disease usually means a poor prognosis, but this correlation has been our clinical impression.

The etiopathogenesis of Hodgkin's disease has yet to be discovered. Certainly the disease has some of the characteristics both of inflammation and of tumor. Most clinicians and pathologists[6] today divide the cases of Hodgkin's disease into 3 categories: (1) paragranuloma, (2) granuloma and (3) sarcoma. Most likely, bone involvement does not occur in Hodgkin's paragranuloma. This is a benign form of Hodgkin's disease that resembles an infection more than a tumor. Often Hodgkin's paragranuloma may progress to the granuloma form, which is the usual form of the disease seen clinically. Hodgkin's granuloma is characterized by irregular bouts of fever, weakness, anemia, leukocytosis and neoplastic formation in organs containing reticuloendothelial cells. Back pain is a very common complaint in patients with Hodgkin's granuloma; this may be due to involvement of retroperitoneal

INCIDENCE OF BONES INVOLVED WITH HODGKIN'S DISEASE IN 44 PATIENTS

SITE OF DISEASE	NUMBER OF PATIENTS*
Lumbar spine	20
Rib	19
Ilium	15
Thoracic spine	9
Sternum	6
Femur	6
Cervical spine	3
Pelvis (other than ilium)	3
Scapula	2
Sacrum	2
Skull	2
Humerus	1

* 22 patients had lesions in more than 1 bone.

glands or to involvement of the vertebral bodies themselves.

Hodgkin's granuloma may progress to the more virulent and more quickly fatal form of Hodgkin's sarcoma. This form has all the characteristics of a true neoplasm, and the majority of patients die within 1½ years of the apparent onset of the disease.

The final diagnosis of these 3 forms of Hodgkin's disease must rest with the pathologist. In each form the characteristic Reed-Sternberg cells must be seen to establish a positive diagnosis.

Any bone in the body may be involved with Hodgkin's disease, but certain bones are affected much more commonly. The spine is a reservoir for metastatic lesions from malignant lesions in various parts of the body. In Hodgkin's disease, the lumbar spine probably is involved more often than is any other bone. Obvious tumor formation may accompany involvement of the skull, the sternum or the ribs, but palpable masses seldom are encountered in the spine or the extremities. The table on page 242 shows the frequency of involvement of each bone in our series of 44 cases. The lumbar spine, the pelvis and the ribs were the bones most often involved. In 22 of these 44 cases there were 2 or more different bones involved.

SUMMARY

The orthopaedist must remember Hodgkin's disease when confronted with the differential diagnosis of an apparently malignant bone lesion. In the absence of lymphadenopathy, a biopsy specimen of the bone lesion must be obtained to establish the correct diagnosis. Most often, the bone lesions of Hodgkin's disease are osteolytic, but osteoplastic lesions also occur. Roentgen therapy usually will eliminate the pain, but it has little effect on bone regeneration and repair

REFERENCES

1. Benda, C.: Zur Histologie der pseudoleukämischen Geschwülste, Zentralbl. allg. Path. 15:542-543, 1904.
2. Blount, W. P.: Hodgkin's disease; an orthopaedic problem, J. Bone & Joint Surg. 11: 761-770, 1929.
3. Dresser, R., and Spencer, J.: Hodgkin's disease and allied conditions of bone, Am. J. Roentgenol. 36:809-815, 1936.
4. Falconer, E. H., and Leonard, M. E.: Skeletal lesions in Hodgkin's disease, Ann. Int. Med. 29:1115-1131, 1948.
5. Heider, K.: Ueber Knochenlymphogranulomatose mit besonderer Berücksichtigung der primären Erscheinungsform, Ztschr. klin. Med. 136:240-257, 1939.
6. Jackson, H., Jr., and Parker, F., Jr.: Hodgkin's Disease and Allied Disorders, New York, Oxford, 1947.
7. Lieberman, H. S.: Hodgkin's disease of bones, J. Bone & Joint Surg. 20:1039-1044, 1938.
8. Livingston, S. K.: Hodgkin's disease of skeleton without glandular involvement; case report proved by autopsy, J. Bone & Joint Surg. 17:189-194, 1935.
9. Montgomery, A. H.: Hodgkin's disease of bones, Ann. Surg. 87:755-766, 1928.
10. Reed, D. M.: On pathological changes in Hodgkin's disease, with especial reference to its relation to tuberculosis, Johns Hopkins Hosp. Rep. 10:133-196, 1902.
11. Steiner, P. E.: Hodgkin's disease; the incidence, distribution, nature and possible significance of the lymphogranulomatous lesions in the bone marrow; review with original data, Arch. Path. 36:627-637, 1943.
12. Sternberg, C.: Ueber eine eigenartige unter dem Bilde der Pseudoleukämie verlaufende Tuberculose des lymphatischen Apparatus, Ztschr Heilk. 19:21-90, 1898; cited by Jackson, H., Jr., and Parker, F., Jr. (See Ref. 6)
13. Uehlinger, E.: Ueber Knochen-Lymphogranulomatose, Virchows Arch. path. Anat. 288:36-118, 1933.
14. Young, J. M., and Funk, F. J., Jr.: Incidence of tumor metastasis to the lumbar spine; comparative study of roentgenographic changes and gross lesions, J. Bone & Joint Surg. 35A:55-64, 1953.

Morbo de Hodgkin in Osso

Summario in Interlingua

Morbo de Hodgkin es frequentemente complicate per le affection de osso. Il occurre que un lesion ossee es le prime signo que attrahe le attention del patiente e induce le a consultar un orthopedista pro obtener un alleviation de su dolores. Quando lymphadenopathia es minimal, le diagnose correcte se face rarmente sin biopsia.

Morbo de Hodgkin in osso pote simular carcinoma metastatic, myeloma multiple, sarcoma osteogene, osteomyelitis, e altere affectiones ossee. Le lesiones ossee de morbo de Hodgkin es le plus frequentemente osteolytic, sed lesiones osteoplastic es etiam possibile. Le orthopedista debe prender morbo de Hodgkin in consideration quando ille attacca le problema del diagnose differential de un apparentemente maligne lesion de osso.

Il existe nulle completemente satisfacente therapia pro iste condition. Roentgenotherapia resulta usualmente in un alleviamento del dolores.

22

Os Calcis Fractures into the Subastragalar Joint

E. J. Nordby, M.D.*

My introduction to fractures of the os calcis occurred during an internship: a rather enthusiastic general surgeon, meaning to impress me by his traumatic approach, grabbed a metal perineal post from a Hawley fracture table and beat the injured heel into proper shape. It was my painful duty following the hasty demonstration to inform him that he had attacked the wrong foot! It was somewhat difficult to explain to the patient the following day the fact of bilaterally painful heels.

PURPOSE

A truly comparative study of fractures of the os calcis is probably impossible, since few of the fractures themselves are comparable. In this attempt I have selected 20 patients representing 22 fractures of the os calcis having in common the entrance of the fracture line into the subastragaloid joint. They were selected from some 36 fractures of the os calcis treated over the 10-year period 1947 to 1957. Comparative study of treatment is even more difficult because of the many forms and variations that it assumes in its application to differing types of fractures of the os calcis. Treatment recommended and carried out even currently varies from several series using no reduction or immobilization and only exercises to manipulations, compressive and bludgeoning reduction maintained by cast, application of pins or spikes as tractors, distractors or levers, open reduction with maintenance of position by screws, staples or bone graft, and excision of the entire os calcis and suture of the tendoachillis to the plantar fascia.

CLASSIFIED TREATMENT

Three general types of treatment are included in this study. One type is that of closed manipulation and molding, sometimes aided by use of a Bohler clamp, and usually applying a molded cast to maintain reduction or whatever improvement in position has been realized, or at least to immobilize the painful foot. Nine cases of an average age of 45 years are included.

The second type is an adaptation of the double transfixion and traction method of Bohler, which I have called the 2-pin treatment. One Steinmann pin is placed in the lower tibia, the other in the tuberosity of the os calcis, and the Bohler or the McMillan frame is used to distract the compressed fragments. The Bohler clamp was used to decrease the widening of the heel, the pins and the leg encased in a short-leg plaster cast. Five cases of an average age of 44 years were included in this category.

The third type of treatment is a form of open reduction described by Lenormant and Wilmoth, of France, in 1932; Gordon Murray, of Canada, in 1940; and popularized, in 1948, by Ivar Palmer of Sweden. The incision is made beneath the lateral malleolus,

* Madison, Wis.

FIGS. 3 and 4, Case D. R. Fig. 3. (*Left*) Lateral view of compressed comminuted fracture of the right os calcis on January 21, 1957. (*Right*) Lateral view during surgery, showing reduction, bone graft and radiopaque sponge.

FIG. 4. Plantar and lateral views of the right os calcis showing end-result on October 17, 1957, after the Palmer operation.

introduced into the compressed bone to lever the superior articular surface into place, leaving a bony defect often the size of a thumb. Into this defect a bone graft is placed, usually iliac bone, which then maintains the position and stabilizes the entire reduction. The Kirschner wire is removed, and a short-leg cast is applied and left in place about 7 weeks. Eight cases of an average age of 46 years received this type of treatment.

Following removal of the cast in any form of treatment, the swelling is controlled by soaking, exercising and elastic bandaging. When clinical and roentgenographic examination indicates weight-bearing, it is allowed only when a firm shank shoe is used, aided by crutches, which then are discarded gradually.

COMMENTS

As might be anticipated, the hospital stay averages about 14 days for the open reduction, about 7 days for the 2-pin fixation, and about 4 days for the uncomplicated closed manipulative treatment with cast. When a cast was used as a part of the treatment in all categories, there was little difference in average duration; it ranged only from 52 to 53 days and was probably more a reflection of the insistence of the physician than the needs of the fracture. Fractures of the left os calcis outnumber those of the right 14 to 8, consistent with other reports. Probably the most significant difference from a morbidity and economic standpoint is the average return-to-work date of 110 days for the Palmer operation, of 154 days for the cast treatment and of 141 days for the 2-pin fixation.

While a satisfactory reduction of the articular surfaces of the os calcis appears to indicate the increased probability of a painless foot in weight-bearing, it is no guarantee of complete absence of discomfort. In the case illustrated in Figure 5, the articular surface appears to be quite satisfactory, but the patient has had persistently disabling

FIG 5 Case S. S. Plantar and lateral views of the left os calcis on October 3, 1957, after closed treatment and cast.

FIGS. 6 and 7, Case L. F. Fig. 6. (*Left and center*) Plantar and lateral views of compressed comminuted fracture of right os calcis July 2, 1957. (*Right*) Lateral view of reduction and graft at surgery.

pain, even at rest, since his injury about 3 years ago. A complicating factor is severe diabetes; it has been difficult to control this, and it may provide an element of diabetic neuritis. However, it is noted that in the open reductions, complaint of pain is limited largely to aching with weather changes or prolonged weight-bearing and uniformly has been of minor consequence in the resulting permanent disability rating. In the 2-pin fixation this also was true, as the only patient with disabling pain had a distraction of fragments that resulted in poor articular congruity.

ROENTGENOGRAPHIC CORRELATION

No direct correlation can be made between apparent congruity of articular sur-

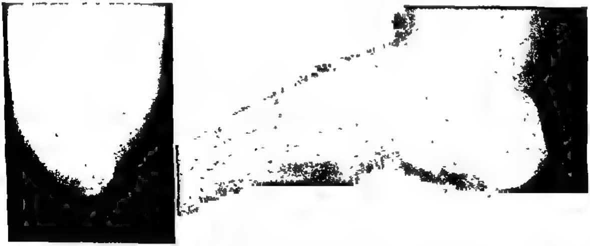


FIG 7. Plantar and lateral views of the right os calcis showing healing on February 18, 1958, following Palmer procedure. Some of the reduction was lost.

introduced into the compressed bone to lever the superior articular surface into place, leaving a bony defect often the size of a thumb. Into this defect a bone graft is placed, usually iliac bone, which then maintains the position and stabilizes the entire reduction. The Kirschner wire is removed, and a short-leg cast is applied and left in place about 7 weeks. Eight cases of an average age of 46 years received this type of treatment.

Following removal of the cast in any form of treatment, the swelling is controlled by soaking, exercising and elastic bandaging. When clinical and roentgenographic examination indicates weight-bearing, it is allowed only when a firm shank shoe is used, aided by crutches, which then are discarded gradually.

COMMENTS

As might be anticipated, the hospital stay averages about 14 days for the open reduction, about 7 days for the 2-pin fixation, and about 4 days for the uncomplicated closed manipulative treatment with cast. When a cast was used as a part of the treatment in all categories, there was little difference in average duration; it ranged only from 52 to 53 days and was probably more a reflection of the insistence of the physician than the needs of the fracture. Fractures of the left os calcis outnumber those of the right 14 to 8, consistent with other reports. Probably the most significant difference from a morbidity and economic standpoint is the average return-to-work date of 110 days for the Palmer operation, of 154 days for the cast treatment and of 141 days for the 2-pin fixation.

While a satisfactory reduction of the articular surfaces of the os calcis appears to indicate the increased probability of a painless foot in weight-bearing, it is no guarantee of complete absence of discomfort. In the case illustrated in Figure 5, the articular surface appears to be quite satisfactory, but the patient has had persistently disabling

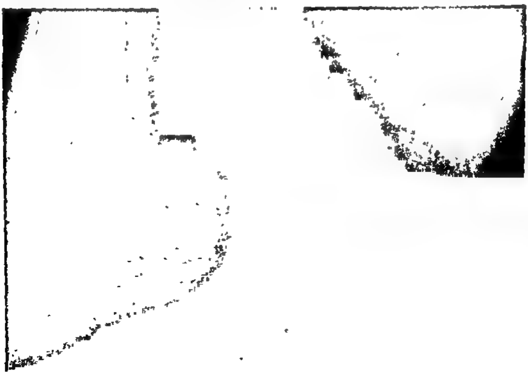


FIG 5 Case S S. Plantar and lateral views of the left os calcis on October 3, 1957, after closed treatment and cast.

FIGS 6 and 7, Case L. F. Fig. 6. (*Left and center*) Plantar and lateral views of compressed comminuted fracture of right os calcis July 2, 1957. (*Right*) Lateral view of reduction and graft at surgery.

pain, even at rest, since his injury about 3 years ago. A complicating factor is severe diabetes; it has been difficult to control this, and it may provide an element of diabetic neuritis. However, it is noted that in the open reductions, complaint of pain is limited largely to aching with weather changes or prolonged weight-bearing and uniformly has been of minor consequence in the resulting permanent disability rating. In the 2-pin fixation this also was true, as the only patient with disabling pain had a distraction of fragments that resulted in poor articular congruity.

ROENTGENOGRAPHIC CORRELATION

No direct correlation can be made between apparent congruity of articular sur-

FIG. 7 Plantar and lateral views of the right os calcis showing healing on February 18, 1958, following Palmer procedure. Some of the reduction was lost.

introduced into the compressed bone to lever the superior articular surface into place, leaving a bony defect often the size of a thumb. Into this defect a bone graft is placed, usually iliac bone, which then maintains the position and stabilizes the entire reduction. The Kirschner wire is removed, and a short-leg cast is applied and left in place about 7 weeks. Eight cases of an average age of 46 years received this type of treatment.

Following removal of the cast in any form of treatment, the swelling is controlled by soaking, exercising and elastic bandaging. When clinical and roentgenographic examination indicates weight-bearing, it is allowed only when a firm shank shoe is used, aided by crutches, which then are discarded gradually.

COMMENTS

As might be anticipated, the hospital stay averages about 14 days for the open reduction, about 7 days for the 2-pin fixation, and about 4 days for the uncomplicated closed manipulative treatment with cast. When a cast was used as a part of the treatment in all categories, there was little difference in average duration; it ranged only from 52 to 53 days and was probably more a reflection of the insistence of the physician than the needs of the fracture. Fractures of the left os calcis outnumber those of the right 14 to 8, consistent with other reports. Probably the most significant difference from a morbidity and economic standpoint is the average return-to-work date of 110 days for the Palmer operation, of 154 days for the cast treatment and of 141 days for the 2-pin fixation.

While a satisfactory reduction of the articular surfaces of the os calcis appears to indicate the increased probability of a painless foot in weight-bearing, it is no guarantee of complete absence of discomfort. In the case illustrated in Figure 5, the articular surface appears to be quite satisfactory, but the patient has had persistently disabling

FIG 5 Case S. S Plantar and lateral views of the left os calcis on October 3, 1957, after closed treatment and cast.

FIGS. 6 and 7, Case L. F. Fig. 6. *(Left and center)* Plantar and lateral views of compressed comminuted fracture of right os calcis July 2, 1957. *(Right)* Lateral view of reduction and graft at surgery.

pain, even at rest, since his injury about 3 years ago. A complicating factor is severe diabetes; it has been difficult to control this, and it may provide an element of diabetic neuritis. However, it is noted that in the open reductions, complaint of pain is limited largely to aching with weather changes or prolonged weight-bearing and uniformly has been of minor consequence in the resulting permanent disability rating. In the 2-pin fixation this also was true, as the only patient with disabling pain had a distraction of fragments that resulted in poor articular congruity.

ROENTGENOGRAPHIC CORRELATION

No direct correlation can be made between apparent congruity of articular sur-

FIG. 7 Plantar and lateral views of the right os calcis showing healing on February 18, 1958, following Palmer procedure. Some of the reduction was lost.

faces to routine roentgenographic study and the integrity of the subastragaloid motions of pronation and supination. Undoubtedly, periarticular fibrosis plays a part in limiting this range of motion if there is a situation similar to that noted in exposing these articulations for arthrodesis. The limitation of subastragaloid motion is a major factor in permanent disability in all cases of fracture of the os calcis, but it appears to be limited most consistently to about 60 per cent of normal in those treated by the Palmer operation.

The decrease of pronation and supination in a pain-free subastragaloid joint does not appear to be regarded as a significant hindrance to function of the foot by those not concerned with a percentage disability rating. One patient walks 6 to 8 miles a day on occasion over rough ground and without pain while having only a 10° range of subastragaloid motion. Mrs. L. F. (Figs. 6 & 7) dances an hour or more at a time without complaint with similar limitation of motion.

DISABILITY RATING

Rated as compared with amputation at the ankle by Wisconsin rules, the average percentage of permanent disability varies little in the groups. Closed manipulation treatment averaged 17 per cent permanent partial disability rating; the 2-pin method, 16 per cent; and the Palmer operation, 12 per cent. The average disability rating appears to be a much more usual outcome in the Palmer operation and the 2-pin method than in the closed manipulation. In the latter category there was either a disability around 25 per cent or no disability at all. Unfortunately, the average disability means little to the individual if he sustains a highly disabling end-result.

Multiple views to include those taken in inversion and eversion are necessary to

FIGS. 8-12, Case R. J. Fig. 8. (*Right*) Lateral view of right os calcis on February 19, 1955, 1 hour after 22-foot fall, showing compression. (*Left*) Lateral view the following day, no treatment having been given, showing "recoil from compression."

make an accurate assessment of the multiplane articulations of the os calcis. Often, the discrepancy of the appearance of the subastragaloid articulations in the routine plantar and lateral views and that seen at operative exposure is startling, with cartilaginous surfaces pitched in all directions and half buried in the compressed cancel-

FIG. 9. (*Right*) Lateral view of the left os calcis February 19, 1955, 1 hour after 22-foot fall, showing compression and comminution (*Left*) Lateral view the following day, no treatment having been given, showing "recoil from compression."

FIG. 10. Plantar view of (*left*) left os calcis and (*right*) right os calcis on February 19, 1955, showing compression and comminution of fracture.

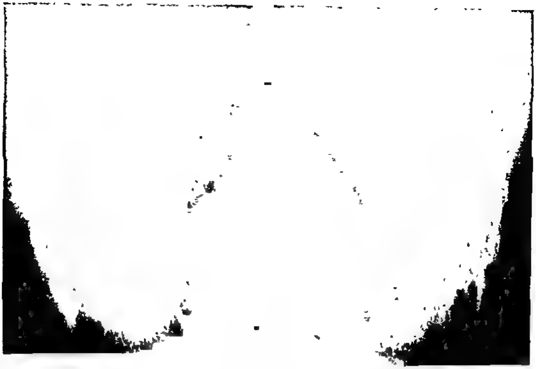


Fig. 11. (*Right*) Plantar view of left os calcis showing degree of healing January 15, 1958, following the Palmer operation (*Left*) Plantar view of right os calcis after initial closed treatment followed by subastragaloid arthrodesis 1 year later.

Fig. 12. (*Right*) Lateral view of left os calcis on January 15, 1958, showing healing after the Palmer operation (*Left*) Lateral view of right os calcis on January 15, 1958, showing healing following subastragaloid arthrodesis

lous bone. It is difficult to see how such distortion could be corrected by closed means. It also makes one appreciate the tolerance of this weight-bearing articulation to deformity that makes possible some satisfactory end-results of very conservative treatment.

Fortuitous timing of roentgenographic studies immediately after injury in the case depicted in Figures 8 to 12 furnishes rather graphic evidence of the compression effect and resilient recoil possible in severe fractures of the os calcis. After only elevation of the foot and bed rest, marked improvement is noted in the compressed comminuted fractures of both ossa calcis after 24 hours. After observing this phenomenon, I suspect that many of the fractures of the os calcis, in which roentgenograms have been made a day or two after injury, actually sustain considerably more compression of the supporting cancellous bone than is realized. This case is probably the only truly comparative study of closed manipulation and open reduction in this series. The right foot was treated by closed manipulation and cast; the left, by Palmer operation. The left foot has been the better one ever since weight-bearing was allowed. Because of increasingly disabling pain in the right foot, a subastragaloid arthrodesis was performed 1 year after his injury. This improved his situation, but the result did not equal that obtained in the left foot. However, at present he operates a restaurant and is on his feet almost continuously from 5:00 A.M. to 10.00 P.M. daily, changing shoes 4 times during that period.

When no comminution of the calcaneal articular surfaces is present, closed manipulation and compression would seem to offer sufficient prospects of a satisfactory end-result. This tenet has been followed in this series, as 7 of the 9 fractures in the closed manipulative treatment have been done since the Palmer operation has been utilized.

Apparently it is possible, on occasion, to obtain a satisfactory functional result in comminuted fractures of the os calcis with one of several types of treatment. However, from these limited observations, including the objective findings and subjective testimony, it is my conclusion that a fracture of the os calcis with compression and comminution into the subastragaloid joint deserves open reduction and bone graft similar to the Palmer operation.

BIBLIOGRAPHY

Brickerton, J. G.: Compression reduction in treatment of fractures of the calcaneus, J. Bone & Joint Surg. 32B:750, 1950.

Campbell, W. G.: A simple operation for reduction of fractures of the os calcis, Brit. M. J. 2:651, 1941.

Cleminson, K.: Excision of calcaneus for fracture, J. Bone & Joint Surg. 34B:158, 1952.

Ehalt, W.: Primary subastragaloid arthrodesis for fractures of the os calcis, J. Bone & Joint Surg. 33A:1037, 1951.

Essex-Loprest, P.: Results of reduction in fractures of the calcaneus, J. Bone & Joint Surg. 33B:750, 1950.

Ferciot, C. F., and Stone, F. P.: Management of fractures of the os calcis, Nebraska M. J. 34:55, 1949.

Murray, G.: Compression fractures of the os calcis, Canad. M. A. J. 42:422, 1940.

AVERAGE RETURN-TO-WORK DATE AFTER TREATMENT

TREATMENT	CASES	AVERAGE AGE OF PATIENT	AVERAGE IN DAYS: Hospital	In Cast	Return to Work	AVERAGE PERMANENT DISABILITY
Closed and cast...	9	45	4	52	154	17%
Two-pin	5	46	7	52	141	16%
Palmer	8	45	14	53	110	12%

Olson, P. F.: Treatment of fractures of the os calcis, J. Bone & Joint Surg. 21:747, 1939.
Palmer, I.: The mechanism and treatment of fractures of the calcaneus, J. Bone & Joint Surg. 30A:2, 1948.
Schoolfield, B. L.: A newer method in the treatment of fractures of the os calcis, Texas J. Med. 40:294, 1944.
Whittaker, A. H.: Open reduction treatment of fractures of the os calcis, Indust. Med. 23:493, 1954.
Wilson, G. E.: Fractures of the calcaneus, J. Bone & Joint Surg. 33A:1037, 1951.
Yoerg, O. W.: An improved treatment for os calcis fractures, Minnesota Med. 21:28, 1938.

Fracturas del Calcaneo A in le Articulation Subastragular

Summario in Interlingua

Un studio vermente comparative de fracturas del calcaneo es probabilemente impossibile. Pro le presente tentativa, vinti patientes esseva seligite con vinti-duo fracturas del calcaneo le quales attingeva le articulation subastragaloide.

Manipulation claudite esseva usate in nove casos. Le etate medie de iste patientes esseva quaranta-cinque annos. Distraction a duo clavos pro reduction mantenite in ingypsation esseva usate in cinque casos. Le etate medie de iste patientes esseva quaranta-quatro annos. Reduction aperte con graffo de osso e mantenentia de position per le methodo popularisate per Ivar Palmer in 1948 esseva usate in octo casos. Le etate medie de iste patientes esseva quaranta-sex annos.

Le plus significative differentia inter le tres methodos esseva un reduction del morbiditate in le caso del methodo de Palmer. Iste reduction amontava a quaranta-quatro e trenta-un dies, respectivemente. Ben que le calculate invaliditate permanente medie sub le conditiones del reduction aperte esseva solmente 4 a 5 pro cento minus que sub le conditiones del reduction claudite, illo esseva plus predicibile in le prime del duo casos e multo plus grande o bassissime in le secunde.

In casos sin comminution del superficie calcaneo-articular, manipulation claudite con compression offere un bon prospecto pro resultatos satisfactori, sed quando le superficie articular es comprimite e comminuite, reduction aperte e graffo de osso simile al methodo de Palmer es recommendate, proque in tal casos illo promitte un satis bon prospecto pro le obtention de un function satisfactori.

23

Dupuytren's Contracture

A Report of Surgical Correction in 83 Cases (1945-1957)*

WILLIAM E. BROWNE, M.D., F.A.C.S.†

This chapter reports the results of 134 operations in 83 cases of Dupuytren's contracture during the 13-year period from 1945 through 1957. Brief reference is made to pathology and etiology of the disease; the anatomy and the operative technics are described, and the work of other authors is discussed briefly.

DESCRIPTION

Adequate familiarity with the gross and the microscopic anatomy of structures involved in Dupuytren's contracture is a necessity before undertaking surgery. Its anatomy and histopathology have been well described by Kaplan,[6] Meyerding[11] and Larsen and Posch.[8] Figures 613 and 624 in *Toldt's Atlas*[12] show very clearly the anatomy of the palmar aponeurosis and its ramifications; also the important anatomy of the lumbricals, the interossei and the extensor structures of the metacarpophalangeal joints. Jones[4] described the development of the palmar fascia and noted clearly diagrammatically the position of neurovascular structures at the level of the webs of the fingers.

The surface marking of the underlying superficial palmar arch may be represented roughly by a line extending from the web of the fully abducted thumb diagonally across the hand to the distal end of the fifth metacarpal bone. Large branches from this arch bifurcate at about the mid-point of the web, sending important vessels along the sides of the digits. With these vessels are the peripheral branches of the median and the ulnar nerves. The deep palmar arch lies a fingerbreadth proximal to the line of the superficial arch.

Ramifications of thickened palmar aponeurosis dip down deeply and are attached in some degree to the fascial covering of the lumbrical and the interossei muscles. In order to avoid damage to nerves, blood vessels and tendons, one must keep constantly in mind during these lengthly dissections the anatomy and, indeed, the physiology of the hand. In this disease, very frequently subcutaneous fat is thinned out markedly, and in operating one comes quickly upon the thickened aponeurosis. Blood vessels and nerves do not penetrate but become markedly adherent to this thickened fascia. At times, nerves are displaced appreciably, especially at the metacarpophalangeal level and also along the proximal phalangeal part of a finger. The neurovascular bundle is found about ⅛ inch from the margins of flexor tendons. Therefore, the flexor tendon becomes an important landmark, and dissection on either side readily uncovers nerves and blood vessels.

Literature on this subject has emphasized in some degree changes in the skin

* From the Department of Surgery, Carney Hospital, Boston, Mass

† Former Clinical Professor of Surgery, Tufts University School of Medicine, Boston, Mass.

in Dupuytren's contracture. As already noted, subcutaneous fat is much thinned out and, in places, gone. The aponeurosis becomes fixed to the deeper layers of the skin, causing changes, particularly in the papillary and the reticulated layers. Irreversible involvement of the layers of the corium deprives it of the elasticity which is so important to normal finger function, necessitating increasing recourse to skin grafts. Although, histologically, the skin on the dorsum of the hand is the same as that on the palm and the volar surfaces of the fingers, it is looser, more pliable and more readily separable from underlying structures. On the dorsum of the hand the skin can be picked up; on the volar surface it cannot. This is true also regarding skin surfaces in the webs of the fingers.

There has been no material progress in identifying the etiology of this condition since its description by Dupuytren in 1832. Some regard it as a chronic inflammatory process. Kanavel, Koch and Mason,[5] in their classic description, refer to familial tendencies. There was a familial history in 11 cases in this series. Meyerding[10] suggested that local trauma might be a factor and could aggravate a pre-existing condition. An actual relationship between trauma and the development of these contractures has never been clearly demonstrated. It would probably be imaginative to consider it at all an uncontrolled physiologic process. The late Sir William Arbuthnot Lane, of Guy's Hospital in London, years ago referred to changes about the metacarpophalangeal joint of the thumb in British coal pickers. He referred to calcification along supportive structures as something giving reinforcement to a constantly used joint. One's reasoning would be stretched considerably in picturing these great thickenings of palmar aponeurosis as something giving support to the hand in various individuals. However, hypertrophy of and some fibrosis in muscles of the thenar eminence were noted repeatedly during World War II in females who complained of fatigue and pain in the hand following long periods of work on heavy material used in the making of uniforms.

Dupuytren's contracture is encountered relatively infrequently among laborers and others whose hands are used very forcibly 40 hours a week. It is found more often among physicians, musicians, cigar makers, clergymen, millworkers, linotype operators, painters and leather cutters working by hand. These are affected more often than truck drivers, stonemasons or carpenters.

OPERATIVE PROCEDURES

Grade 1. A somewhat thickened nodule in the aponeurosis with dimpling of the skin along the fourth or the fifth metacarpal areas.

Seldom is any difficulty encountered in the treatment of these Grade 1 conditions. Incision, as indicated, is made; fascia is removed, and bleeding is controlled; drainage, if necessary, is through a small incision, and the skin edges are brought together neatly without tension.

Grade 2. Definitely palpable pretendinous bands without appreciable contractures.

The procedure in these cases is similar to that followed in Grade 1, but with further excision of fascia. Slight restriction of full extension in the first (metacarpophalangeal) joint may result, but seldom exceeding 10°, and flexion well within normal limits.

Grade 3. Induration and puckering of the skin, with up to 50° of contracture in both first and second (proximal interphalangeal) joints.

Complete, sometimes referred to as radical, dissection is carried out. In some of these cases the skin is hopelessly involved and is sacrificed. This is followed by an intermediate or full-thickness graft. A pedicle graft has not been used in any of this series.

Grade 4. Marked puckering of the palm; marked contracture in the first and frequently right-angle contracture, or slightly

more, in the second joints, with occasional hyperextension of a distal joint. Torsion or twisting of the fifth finger, causing it to impinge against the fourth; contracture of the fifth finger resulting (in 1 case) in actual ulceration of the palm.

An extensive procedure is carried out, associated very frequently with skin-grafting. One side or both sides of a finger are dissected, often to the mid-phalangeal area. In 4 cases in this group, an arthroplasty was done with removal of the distal end of the proximal phalanx. A layer of available fibroareolar tissue is interposed between the smoothed cut end of the proximal phalanx and the mid-phalanx. Of course, there has been very little flexion in such made-over joints, although in 3 of these 4 cases motion was worth while. Of 5 poor results encountered in Grade 4 cases, 2 eventually required amputation of the little finger. When this is done, the distal end of the metacarpal is removed obliquely, and the cut bony surfaces are beveled, leaving a rather natural contour of the skin with less disfigurement than might be expected.

RESULTS

Classification

Perfect. There were 2. No discernible anatomic deformity, with a fine-line, nondisfiguring scar; no loss of function.

Excellent. There were 49. Full flexion and nearly full extension of all fingers with good interossei action. No sensitiveness in scars (Fig. 1).

Good. 67. Most of the cases in the series fall in this category, and, with few exceptions, these patients have been satisfied with the result. In some cases there has been a loss of extension in the first or the second joints up to 15 to 20° and very close to full flexion in both joints.

Fair. 11 cases. Although in these cases extension was restricted up to 40° in joints, none-the-less the patients were able to return to their occupations and generally were satisfied that they had been benefited appreciably.

Figs. 1 to 6, same patient. Fig. 1. Before operation; note contractures in fifth and fourth fingers with band involving proximal phalangeal part of ring finger.

Poor. There were 5. Contractures had been relieved somewhat by operation, but residual stiffness in each case prevented worth-while use of the fifth finger. In the poorest result there was very great restriction of motion in the fifth and the fourth digits of the right hand. Surgery had previously been carried out elsewhere in 2 of these cases. Had the condition of these hands been evaluated better, complete dis-

Summary. 134 Operations on 83 Patients

Male		72
Female		11
Ages (24 to 72 years)	Average	52 8/12
Stay in hospital	Average	6 days
Bilateral		52
Single		31
Grade 1		14
2		26
3		45
4		49
Disability (1 to 152 days)	Average	41 days
Skin graft		27
Recurrences		3
Amputation of little finger		3
Arthroplasty		4
Results:		
Perfect		2
Excellent		49
Good		67
Fair		11
Poor		5

FIG. 2. Showing dissection of entire palm. Note nerves and blood vessels gently retracted to permit removal of all involved fascia.

section would not have been carried out without preoperative permission in writing for removal of the fifth digit if this was found to be advisable. It is again noted that in 3 of these 5 cases, amputation of the little finger was done.

Length of Disability

The criterion for disability was the number of days the patient was required to be absent from daily work. A male bookkeeper returned to work on the second day after operation. A baker was away from work for the longest stretch—152 days. A garage mechanic, who developed marked thickening in each palm that never fully disappeared, was disabled for 146 days. The average period of disability for all grades was 41 days.

Recurrences

There were 3 known recurrences following our own operations in this series. One was a Grade 4 case with bilateral involvement, in which an arthroplasty was fashioned on the ankylosed proximal joint of the fifth left digit. In a dissection of the right hand 5 days later (without arthroplasty), a long, thickened pretendinous band was removed along the fifth digit, ending just distal to the terminal interphalangeal joint. In both procedures the results were believed to be satisfactory. However, 3 years later, this patient returned with marked contractures in the first and the second joints of the fifth right digit. At operation the thickened pretendinous band was found to have reappeared in the proximal and the midphalangeal areas. An arthroplasty was done in the fifth digit. Each fifth finger is shortened somewhat. This patient was more pleased than many with the end-result, mindful of the deformities and the loss of function present before treatment was started.

A 65-year-old laundry machine worker and inventor had developed a twisting or torsion of the fifth finger following a complete operation on the palm performed by another surgeon 6 months previously. With the hand at rest, the little finger impinged against the fourth. With attempted use of the hand, the little finger rode under the fourth. His hand was unusually painful. Significant elevations in uric acid and cholesterol values were found, and further operation was delayed for several months. Further dissection of the palm was carried out, together with removal of a long thickened band along the fifth finger similar to that encountered in the case just described. A large skin graft was found to be necessary (Fig. 2). The result was classified as good. At times, classification of grades of involvement and end-results is arbitrary.

DISCUSSION

While preoperative roentgenograms are not always necessary, they were made in all cases in this series in which there was any question of erosion or malalignment of joint surfaces. When underlying systemic disease was suspected, sedimentation rates, blood calcium, uric acid and cholesterol values were determined. In none of these cases were antibiotics used preoperatively. Each of two superficial infections was attributed to hematoma formation, even though meticulous attention had been given to hemostasis

and drainage had been used. Antibiotics were used postoperatively in 7 instances. To disrupt a person's daily routine with operation and such after-care as is needed is, indeed (as Crawford[2] suggests), unnecessary, *unless* finger flexion is progressive. Although it is true that many cases remain static for long periods of time, we know of no means by which one can determine the prognosis accurately in any given case. Therefore, it becomes necessary for one noticing trouble in the hand to undergo examination once or twice a year and keep an accurate record of increasing dysfunction which can readily be measured accurately. One should be advised to submit to operation after full explanation of matters involved when dysfunction is found to be increasing. Resort to surgery before a condition becomes extreme is followed by shorter periods of disability and less dysfunction than when the condition progresses to Grade 4, as classified above.

Subcutaneous division of pretendinous bands was employed in only 2 of these cases. The removal of obviously involved bands through a wavy or curvilinear or sinuous incision, as described by Hamlin[3] was carried out 7 times. This procedure has a very definite place in the management of Dupuytren's contracture. The curvilinear incision used in these cases permits sufficient exposure for removal of thickened bands with adjacent attached ramifications.

A nearly full-length distal palmar flexion crease incision, often with incision along one side or both sides of a finger, has been carried out in operable Grade 3 and 4 cases. Frequently an incision adjacent to the thenar flexion crease is necessary for adequate exposure. When used, the distal end of this incision should not be closer than ¾ inch from the transverse palmar crease incision in order to avoid compromising blood supply so important for proper wound healing. Neither an oblique incision in the proximal phalangeal part of a finger nor Z-shaped incisions have been used in this series.

Nearly 30 years ago, Kanavel, Koch and Mason[5] described their treatment of choice. In a few words they indicated need for complete excision of palmar fascia through a proper incision, sacrificing irreversibly involved skin. The treatment found necessary then is the treatment of necessity today in attempting to do as much as possible for patients with extensive, but remediable, involvement of one hand or both hands. Kaplan[7] reports good results with a fasciotomy, a procedure that he describes as sufficiently mild to be carried out under local anesthesia in many cases. Through very small incisions, skin is separated from underlying fascia, and the fascia is transected, relieving contracted fingers. Disability in many cases amounts to about 10 days. We have had 2 cases in which the procedure described by Kaplan was used.

Frequently, in the early part of Grade 4 dissections, a pretendinous band is transected in the palm and again close to the metacarpophalangeal crease without bringing about any appreciable release of marked contracture in the metacarpophalangeal or proximal phalangeal joint. Emphasis is placed on the marked involvement found frequently at the web and extending along the finger. Removal of involved thickened fascia in this critical area under adequate exposure has been found to be necessary in these series. Seldom has local anesthesia been used, except in Grade 1 cases. Rarely, unless indicated specifically, is brachial block or perineural infiltration carried out.

At present, and for some years past, it has been recognized generally that operations in the hand must be done in a dry, or bloodless, field. A pretested blood-pressure cuff is employed to ensure a dry field. When, during an operative procedure, a blood-pressure cuff becomes faulty with resultant blood in the field, a moist warm Mikulicz pad and towel are wrapped and held firmly about the hand, thus controlling bleeding temporarily.

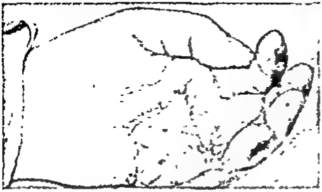


FIG. 3. Completion of skin graft with fingers in natural position; no drainage.

FIG. 5. Fifty-two days after operation. Full extension of fingers.

FIG 4. Dressing, which is so important. Fingers in natural position protrude beyond dressing. Note splint, which is used for about 10 days—two pieces of splint wood hinged together with a strip of adhesive plaster and roller bandage between the two pieces of splint wood, permitting whatever degree of dorsiflexion is found to be necessary. Then a lighter splint.

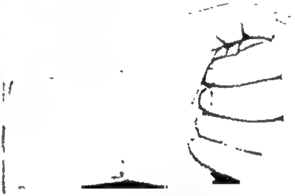


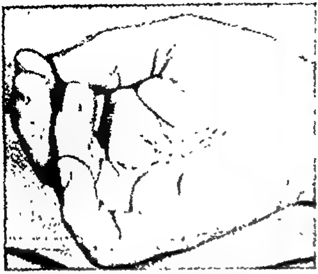
FIG 6. Full flexion of fingers. Classified as an excellent result.

A new blood-pressure cuff is applied rather than to attempt to complete the procedure with structures obscured because of blood in the field. During the process of dissection, tiny blood vessels are recognized, divided and ligated promptly with fine cotton or silk. Upon completion of the dissection, the blood-pressure cuff is deflated. Bleeding points are ligated carefully. The extremity is elevated and compressed. The blood-pressure cuff is again inflated, and closure with or without skin graft and drainage when indicated is carried out.

In other cases—not considered here—fine catgut was used frequently for ligation purposes, resulting at times in small blowout patches in a graft. Frequently, a single strand from a gauze sponge has been found to work well as a ligature. Very fine suture material is used to bring carefully apposed edges of skin together without tension.

Proper instruments, including small retractors, are necessary for adequate exposure. We have found an ordinary safety pin (Fig. 13) can be fashioned quickly into a very usable retractor. The safety pin is opened; it is extended fully using an Ochsner or some firm type of clamp. The tip of the pin is curved at a desirable angle; the point of it is rounded. The central portion may be held between the tip of the thumb and the index finger, and it serves as a very good retractor.

In each of 2 cases the main trunk of a digital nerve was injured in spite of careful dissection. The injury was recognized in



Figs. 7 to 12, same patient. Fig. 7. Note the fifth digit impinging against the fourth—puckered skin in palm.

Fig. 9. Nerves and blood vessels gently retracted to permit removal of deep layers of involved fascia.

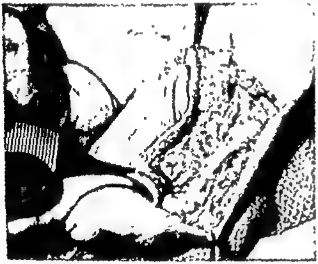


Fig. 8. Markedly thickened band extending along finger to beyond distal flexion crease.

Fig 10. Skin graft in place. Note site of drainage.

each, and the nerve ends were brought together with 2 very fine silk sutures. Somehow, one patient never complained of loss of sensation; numbness in the other persisted for 7 months.

In some cases, healing of superficial layers of the skin has not been entirely satisfactory. Sometimes there has been interference with healing in small segments of a graft. For emphasis, it is noted once more that, notwithstanding hemostasis and adequate pressure dressing, hematoma formation has occurred The importance of proper dressing cannot be overemphasized. The skin surfaces are cleansed; then step by step, large amounts of fluffed gauze first are packed evenly between the fingers, which are allowed to rest in partial flexion. Next, the whole hand is covered evenly, using proper pressure with fluffed gauze. Prolonged immobilization must be avoided. We have not used a plaster-of-Paris cast in any case. A splint has been used (Fig. 4) with the wrist in slight dorsiflexion. The dressing is changed 24 to 36 hours postoperatively for removal of drain when used. The dressing may be changed at any time when necessary, but usually not until the ninth or

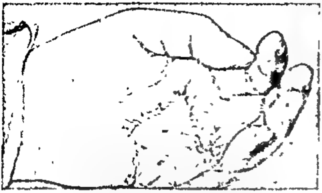


FIG. 3. Completion of skin graft with fingers in natural position; no drainage.

FIG. 4. Dressing, which is so important. Fingers in natural position protrude beyond dressing. Note splint, which is used for about 10 days—two pieces of splint wood hinged together with a strip of adhesive plaster and roller bandage between the two pieces of splint wood, permitting whatever degree of dorsiflexion is found to be necessary. Then a lighter splint.

FIG. 5. Fifty-two days after operation. Full extension of fingers.

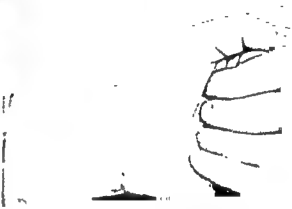


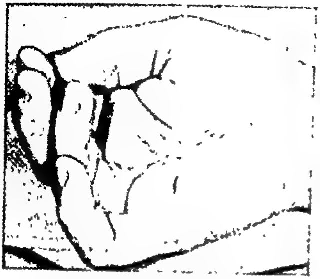
FIG. 6. Full flexion of fingers. Classified as an excellent result.

A new blood-pressure cuff is applied rather than to attempt to complete the procedure with structures obscured because of blood in the field. During the process of dissection, tiny blood vessels are recognized, divided and ligated promptly with fine cotton or silk. Upon completion of the dissection, the blood-pressure cuff is deflated. Bleeding points are ligated carefully. The extremity is elevated and compressed. The blood-pressure cuff is again inflated, and closure with or without skin graft and drainage when indicated is carried out.

In other cases—not considered here—fine catgut was used frequently for ligation purposes, resulting at times in small blowout patches in a graft. Frequently, a single strand from a gauze sponge has been found to work well as a ligature. Very fine suture material is used to bring carefully apposed edges of skin together without tension.

Proper instruments, including small retractors, are necessary for adequate exposure. We have found an ordinary safety pin (Fig. 13) can be fashioned quickly into a very usable retractor. The safety pin is opened; it is extended fully using an Ochsner or some firm type of clamp. The tip of the pin is curved at a desirable angle; the point of it is rounded. The central portion may be held between the tip of the thumb and the index finger, and it serves as a very good retractor.

In each of 2 cases the main trunk of a digital nerve was injured in spite of careful dissection. The injury was recognized in



FIGS. 7 to 12, same patient. Fig. 7. Note the fifth digit impinging against the fourth—puckered skin in palm.

FIG. 9. Nerves and blood vessels gently retracted to permit removal of deep layers of involved fascia.

FIG. 8. Markedly thickened band extending along finger to beyond distal flexion crease.

FIG. 10. Skin graft in place. Note site of drainage.

each, and the nerve ends were brought together with 2 very fine silk sutures. Somehow, one patient never complained of loss of sensation; numbness in the other persisted for 7 months.

In some cases, healing of superficial layers of the skin has not been entirely satisfactory. Sometimes there has been interference with healing in small segments of a graft. For emphasis, it is noted once more that, notwithstanding hemostasis and adequate pressure dressing, hematoma formation has occurred. The importance of proper dressing cannot be overemphasized. The skin surfaces are cleansed; then step by step, large amounts of fluffed gauze first are packed evenly between the fingers, which are allowed to rest in partial flexion. Next, the whole hand is covered evenly, using proper pressure with fluffed gauze. Prolonged immobilization must be avoided. We have not used a plaster-of-Paris cast in any case. A splint has been used (Fig. 4) with the wrist in slight dorsiflexion. The dressing is changed 24 to 36 hours postoperatively for removal of drain when used. The dressing may be changed at any time when necessary, but usually not until the ninth or

FIG. 11. Full extension of metacarpophalangeal joints. Slight restriction in extension of proximal joint of little finger.

FIG 12. Full flexion of all fingers. This is classified as a good result.

the tenth postoperative day. Exercise of the fingers, in so far as the dressing will permit, may commence after the seventh or the eighth day. Dressings are maintained until wound healing is complete, and full finger exercise begins 18 to 21 days postoperatively in Grade 3 or 4 cases; earlier in other cases. Physiotherapy can proceed effectively at home Ordinary exercises, as thorough washing of the hand with soap and water or wringing out a bath towel with both hands, have proven to be as satisfactory in restoring function as more formal physiotherapy. (See Figs. 4-13.)

FIG. 13. Ordinary safety pin fashioned readily into a very satisfactory retractor.

CONCLUSIONS

The majority of the results in this series have been good. A few patients whom we know have required further surgery. Some have complained of numbness, not great in degree, but bothersome for a while in 1 or 2 fingers. *Stiffness is a frequent complaint, and it may persist for weeks. In a very few* cases, the end-result has been poor. It is difficult to make an accurate prognosis in borderline cases. Not all cases of Dupuytren's contracture in any of its forms require, or should have, surgery. The patient should be followed periodically and careful records kept of progress. Physicians should have a very clear idea as to what may be accomplished for many of these patients.

Mason[9] and others have emphasized the importance of early treatment, and the significance of prompt attention to the management of Dupuytren's contracture in its early stages cannot be overstated. Generally it is agreed that early and adequate excision of involved fascia will produce a better result and a shorter period of disability. The unusual insidiousness of onset and the absence of attendant pain caused many patients to ignore the condition or delay therapy. A good many physicians, *including surgeons, have Dupuytren's* contracture, and all too often they do nothing about it until they are incapacitated. One surgeon, having put up with it for some 18 years, finally submitted to operation when he could no longer get on rubber gloves. A radiologist waited until he was unable to use heavily leaded gloves for fluoroscopic work. A pianist submitted to bilateral operations as an alternative to loss of his job; fortunately, he was back at work in 6 weeks after

bilateral operation, which included skin graft on his major hand. One female and 2 male patients, all over 70, sought relief because of inability to play golf; the results were among the best in the series. We have had only 4 patients in whom the thumb was involved and 1 patient only with bilateral fascia involvement of the feet. In this latter patient, both hands also were involved—Grade 2 process—and operation in this case was very satisfactory.

SUMMARY

Some of the more important aspects of Dupuytren's contracture have been presented, with particular reference to anatomic structures and skin changes. Operative procedures of choice, according to the severity of the condition found, have been described. The results of 134 operations in 83 cases have been reported with comments on length of disability and recurrences. Various aspects of operative technic and postoperative management have been discussed. The importance of early treatment has been emphasized.

REFERENCES

1. Browne, W. E.: The necessity for use of splints in the treatment of injuries of the hand, with a demonstration of some of the newer types, New England J. Med. 215: 742-748, 1936.
2. Crawford, H. R.: Surgical correction of Dupuytren's contracture, S. Clin. North America 36:793-800, 1956.
3. Hamlin, E., Jr.: Limited excision of Dupuytren's contracture, Ann. Surg. 135:94-97, 1952.
4. Jones, F. W.: The Principles of Anatomy As Seen in the Hand, Baltimore, Williams & Wilkins, 1942.
5. Kanavel, A. B., Koch, S. L., and Mason, M. L.: Dupuytren's contraction—with a description of the palmar fascia, a review of the literature, and a report of 29 surgically treated cases, Surg., Gynec. & Obst. 48:145-190, 1929.
6. Kaplan, E. B.: Functional and Surgical Anatomy of the Hand, Philadelphia, Lippincott, 1953.
7. ———: Personal communication.
8. Larsen, R. D., and Posch, J. L.: Dupuytren's contracture with special reference to pathology, J. Bone & Joint Surg. 40A:773-793, 1958; and Larsen, R. D., personal communication.
9. Mason, M. L.: Dupuytren's contracture, S. Clin. North America 32:233-247, 1952.
10. Meyerding, H. W.: Discussion of paper by D. T. Shaw entitled "Surgical Repair of Dupuytren's Contracture," at 12th annual meeting of The American Society for Surgery of the Hand held in Chicago, January 25, 1957.
11. ———: The etiology and pathology of Dupuytren's contracture, Surg., Gynec. & Obst. 72:582-591, 1941.
12 Toldt, C.: An Atlas of Human Anatomy for Students and Physicians, New York, Macmillan, 1941.

Contractura de Dupuytren: Reporto de 83 Casos de Correction Chirurgic

Summario in Interlingua

Un causa definite de contractura de Dupuytren non es cognoscite. Dupuytren, describente le condition in 1832, opinava qua trauma repetite esseva un factor etiologic. Varie theorias de pathogenese ha essite promulgate per varie competente investigatores. Le contracturas se disveloppa insidiosemente, e chirurgia—in forma adequate—es le sol tractamento pro illos que vale le pena. Le intervention chirurgic non debe esser interprendite sin exacte cognoscentias del anatomia e physiologia de omne structuras del mano. Contracturas de Dupuytren pote esser gruppate in 4 classes. Le ultime resultatos pote esser describite como perfecte (lo que es rar), excellente, bon, satis bon, e inadequate. In casos de grado 3, graffos cutanee es a vices necessari. In

casos de grado 4, iste necessitate as frequente. Meticulositate in effectuar hemostasis preveni le formation de hematoma. Si isto occurre nonobstante, illo retarda le resanation del vulnere. Le mantenentia del position functional del digitos e del pollice, con immobilisation adequate usque al resanation complete del vulnere, es de importantia essential. Le typo del incision depende del extension del contractura. Le resultatos obtenibile sub conditiones favorabile justifica urger le patientes de acceptar le operation—quanto plus promptemente tanto melio.

24

Technic of the Resection-Angulation Operation for Hip-Joint Disabilities

HENRY MILCH, M.D.*

As its designation indicates, the resection-angulation operation consists of two separate procedures, the validity of both of which has been long established. Resection of the femoral head and neck has been employed in the treatment of tuberculosis and of osteoarthritis of the hip by Girdelstone[3] and others. While this restores mobility of the hip, it converts the femur into a "broomstick" that affords no stability. For the correction of this disability, both Lorenz[6] and Schanz[11] devised operations that have proven to be successful. Experience has demonstrated that the Schanz type of osteotomy is to be preferred, since, for any given degree of abduction of the distal osteotomized portion of the femur, it affords greater stability with less limitation of motion and less shortening of the extremity than does the Lorenz type of osteotomy.[9] Whereas earlier proponents of the subtrochanteric osteotomy believed that high degrees of abduction afforded better results, it was shown subsequently that abduction of the distal portion of the osteotomized femur led to the creation of another angle, "the postosteotomy angle,"[10] the size of which was determined critically by the inclination of the outer wall of the pelvis.[13] Postosteotomy angle values less than that of the pelvic wall inclination do not afford sufficient stability, while values in excess of the critical value result in limitation of motion and apparent shortening of the opposite, unaffected extremity.[8,9]

The resection-angulation operation makes no effort at restoration of the anatomic configuration of the hip joint. On the contrary, the emphasis is placed entirely on the re-establishment of function, of stable, painless motion; and the anatomy is sacrificed completely in eliminating the pathology that necessitated operation. When this operation was first performed in 1934, it was carried out in two stages.[12] As regards the order in which the two stages of the operation were to be performed, it was found to be more convenient to osteotomize the femur in the first stage and resect the head and the femoral neck at a later time. While primary resection of the head reduced the technical difficulties, it raised the problem of preventing upward displacement of the shaft and was abandoned in favor of primary osteotomy. (This is the procedure that later was recommended by Batchelor.[1,2]) In 1946, following description of the blade plate, the operation was performed in a single stage and was reported in 1947.[8] In 1950, Gruca,[4,5] reported an identical modification in the operation, which he used in the treatment of tuberculosis of the hip. Since 1946, over 100 of these one-stage operations have been performed by the writer. The results of the first 64, performed on 56 patients, were reported in 1955.[11]

* New York, N. Y.

FIG. 1. On a symmetric anteroposterior roentgenogram of the whole pelvis, including the upper thirds of the femora, a line AA′ is drawn from the outermost projection of the superior edge of the acetabulum to the most lateral projection of the ischial tuberosity. The line BB′ is drawn between two symmetric points on the pelvis, preferably between the superior projections of the acetabula. At the point where the line BB′ intersects the line AA′, a line CC′, perpendicular to BB′, is drawn. The larger of the angles ACC′ is the measure of the inclination of the outer wall of the pelvis.

Briefly, that study indicated that in the group as a whole, almost complete relief of pain was obtained in 67.2 per cent of the cases and marked improvement in an additional 25 per cent of the cases. Satisfactory restoration of motion was obtained in 53.1 per cent of the cases and improvement in motion in an additional 29.7 per cent of the cases. In the unilateral cases, the results were somewhat better than in the group as a whole. Relief of pain was obtained in 82.8 per cent with diminution of pain in an additional 13.8 per cent of the cases. Satisfactory restoration of motion was accomplished in 65.5 per cent of the cases, with improvement of motion in an additional 20 per cent.

The procedure, including the preoperative preparation of the blade plate used to im-

FIG. 2. The ... cing of the head, the
neck and th... d of the femur has
been cut o... resection of the
head and th... intertrochanteric
line is indi... dashed line. The
femoral sh... cut at the level at
which osteo... performed

mobilize the osteotomized femoral fragments, is as follows:

A symmetric roentgenogram of the pelvis and both hips is made with the pelvis in its relatively normal position. If there is a flexion contracture of the hips, the roentgenogram is made with the thighs flexed to avoid downward tilting of the pelvis. A line is drawn between the most lateral projection of the acetabular rim and the most lateral portion of the ischial tuberosity (AA'); a transverse line is drawn between any two symmetric points of the pelvic roentgenogram, preferably joining the two superior acetabular margins (BB'). A perpendicular line (CC') next is drawn in the downward direction from the point of intersection of the two previously drawn lines. The larger of the two angles between this perpendicular line (CC') and the oblique line (AA') first drawn determines the angle of inclination of the lateral pelvic wall (Fig. 1).

A tracing of the femoral roentgenogram shadow on the side to be operated upon is made, and the level of the osteotomy about 1½ inches below the base of the greater trochanter is marked on a paper tracing. Then the femoral head and neck on the paper tracing are cut away at the intertrochanteric line, leaving the tracing of a broomstick type of femur (Fig. 2). The longitudinal axis of the femoral shaft is drawn on the paper tracing and the tracing is transected at the previously determined level below the lesser trochanter. The femur is angulated so that the axes of the proximal and the distal portions of the femoral shaft make an angle equal to that of the previously determined angle of inclination of the lateral pelvic wall (Fig. 3). A Blount-Moore or other plate with screw holes is angulated so as to conform with the angulated paper tracing (Fig. 4).

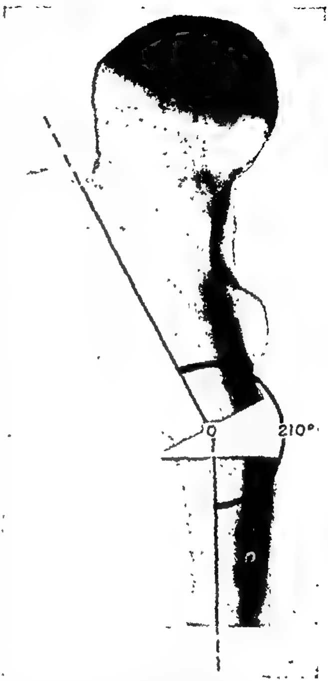


FIG. 3. The femoral shaft has been osteotomized and the distal portion of the shaft has been abducted so that the angle which the axis of the distal portion makes with the axis of the proximal portion is equal to the predetermined angle of inclination of the outer wall of the pelvis.

With the patient in the supine position, a lateral iliofemoral incision is made from just below the anterosuperior iliac spine to the base of the greater trochanter and is continued down along the lateral aspect of the thigh, over the femoral shaft, a distance of about 6 to 8 inches. The skin flaps are developed, and the deep fascia is incised in the line of the skin incision. At the base of the greater trochanter, a small triangular interval between the gluteus medius and the tensor fasciae femoris muscles is identified

FIG. 4. The blade plate has been inserted at the base of the greater trochanter so that the angle is located precisely at the predetermined level of femoral osteotomy. After transection of the femoral shaft, the distal osteotomized fragment is fixed to the plate by screws of appropriate length.

and opened bluntly. The external circumflex vessels are encountered occasionally in this space and must be ligated individually. Separation of the two muscles, by finger retraction, discloses the joint capsule. The nerve to the tensor fasciae femoris muscle may be displaced upward during the course of the blunt dissection, but occasionally it is severed. A Lane retractor then is passed beneath the reflected head of the rectus femoris muscle, which is visualized at the upper anterior portion of the wound, and the tensor fasciae femoris muscle, keeping close to the anterior capsule of the hip joint. Another Lane retractor next is passed posteriorly between the gluteus medius muscle and the posterior portion of the joint capsule. Traction on the Lane retractors exposes the anterior, the posterior and the superior portions of the hip-joint capsule.

The capsule is incised transversely along its superior border, where it passes over the glenoidal margin An anterior and a posterior longitudinal incision is made from the extremities of the transverse incision in the capsule down to the intertrochanteric line. The capsular flap so formed is turned down and left attached at, or slightly above, the intertrochanteric line. The hip joint thus is exposed. The head of the femur is dislocated from the acetabulum by flexion and external rotation of the femoral shaft. If the presence of osteophytes prevents dislocation of the femoral head, these excrescences are cut away by an osteotome. If this, too, is unsuccessful, the femoral head may be removed by morcellation. However, if the head is ankylosed in the acetabulum, no further attempt at release should be made; rather, the femoral neck should be freed by osteotomizing the femoral head flush with the side of the pelvis.

The intertrochanteric line is identified, and the base of the femoral neck is transected by an osteotome at this level, care being taken to avoid damaging the lesser trochanter or the attachment of the iliopsoas muscle. When a deformed head is removed from the acetabular cavity, excessive bleeding is encountered frequently. This can be controlled in most cases by placing oxycel gauze in the acetabular cavity and bone wax on the cut surface of the femoral neck. The capsular flap is sutured down over the base of the transected femoral neck, interrupted chromic catgut sutures being used. The

gluteus medius and the tensor fasciae femoris muscles are loosely approximated, and the fascia, down to the level of the hip of the greater trochanter, is closed, interrupted chromic catgut sutures being used.

The fascia on the lateral aspect of the thigh is opened in the line of the skin incision, and the upper end of the femoral shaft is exposed by sharp division of the fibers of the vastus lateralis muscle. The muscles and the fascia attached to the linea aspera are detached by sharp or blunt dissection. Considerable bleeding may be encountered during this phase of the operative procedure, and it is best controlled by packing with hot laparotomy or Mikulicz pads. The upper end of the femoral shaft to the base of the trochanter is exposed subperiosteally and the upper end of the blade plate is fixed to the upper end of the femoral shaft so that the angle of the plate is directly at the predetermined level (level of the ischial tuberosity) of the osteotomy, usually about 1½ inches below the base of the greater trochanter. Drill holes are made through the femoral shaft at the level of the osteotomy. A Lowman clamp is passed behind the femoral shaft. The osteotomy is completed through the drill holes made previously. The distal osteotomized portion of the shaft is rotated internally about 30° and then abducted to the plate, to which it is firmly fixed by the Lowman clamp. The plate is secured to the distal portion of the femoral shaft by at least 4 screws of appropriate length, and the Lowman clamp is removed. The vastus lateralis is sutured loosely, and the deep fascia is closed by interrupted chromic catgut sutures. The wound is irrigated thoroughly with saline or, if desired, with a 50 per cent solution of a broad-spectrum antibiotic. The skin is closed without drainage. A firm gauze spica pressure dressing is applied.

While the patient is still under anesthesia, the thigh is flexed to a right angle and supported in this position by means of a sling to which a rope, passing over the head of the bed with about 10 pounds of weight, is attached. Active and passive motion is instituted on the second or the third postoperative day, provided that pain is not excessive. Thereafter, active motion is encouraged assiduously. The patient's thigh is released from the position of right-angled flexion and brought into complete extension at least twice daily to prevent contracture of the flexor muscles. Weight-bearing, with the aid of crutches, may be permitted as early as 3 weeks after operation. Within 6 weeks, stair-walking should be encouraged, and, as soon as possible, the use of crutches should be discontinued. If more comfortable, or if gait is improved thereby, the shoe on the side that underwent operation may be elevated about ¾ to 1 inch to compensate for the shortening that follows resection of the femoral head and neck. Exercises to strengthen the flexors and the extensors of the hip are continued until the patient can flex the hip actively to at least 90°.

REFERENCES

1. Batchelor, J. S.: Excision of femoral head and neck for ankylosis and osteoarthritis of hip, Post Grad. M. J. 24:241-248, 1948.
2. ———: Excision of the femoral head and neck in cases of ankylosis and osteoarthritis of the hips, Proc. Roy. Soc. Med. 38: 689-690, 1945.
3. Girdelstone, G R.: Pseudoarthrosis. A discussion on the treatment of unilateral osteoarthritis of the hip. Proc. Roy. Soc. Med. 38:363, 1945.
4. Gruca, A.: Le traitement de la coxalgie par resection de l'articulation et osteotomie. Soc. internationale chirurgicale orthropédique et de traumatologie. Réunion de reprise de contact, Brussels, 1946.
5. ———: The treatment of quiescent tuberculosis of the hip joint by excision and "dynamic" osteotomy, J. Bone & Joint Surg. 32B:174-182, 1950.
6. Lorenz, A.: Über die Behandlung der irreponibilen angeborenen Huftluxationen und der Schenkelhalspseudoarthrosen mittels Gabelung des oberen Femurendes, Wien klin. Wchnschr. 32:997, 1919.

7. Milch, H.: The excessive postosteotomy angle, Bull. Hosp. Joint Dis. 14:235-241, 1953.
8. ———: Osteotomy of the Long Bones, Springfield, Ill., Thomas, 1947.
9. ———: The pelvic support osteotomy, J. Bone & Joint Surg. 23:581-595, 1941.
10. ———: The postosteotomy angle, J. Bone & Joint Surg. 25:394-400, 1943.
11. ———: The resection-angulation operation for hip joint disabilities, J. Bone & Joint Surg. 37A:699-717, 1955.
12. ———: Resection of the femoral with pelvice support osteotomy for an sis of the hip, Surgery 13:55-61, 194
13. Milch, R. A.: Roentgenographic stu the inclination of the lateral pelvic wa the interacetabular distance in normal pelves, J. Bone & Joint Surg. 36A:533 1954.
14. Schanz, A.: Zur Behandlung der ve ten angeborenen Hüftverrenkung, M med. Wchnschr. 69:930-931, 1922.

Le Operation a Resection-Angulation in Casos de Invaliditate del Articulation Coxal

Summario in Interlingua

Le operation a resection-angulation es un manovra que visa a resolver le problema del dolorose restriction de movimentos in le articulation coxal. In le passato, fusion—visante a alleviar le dolor—e subsequentemente varie typos de operation a reconstruction anatomic—pro restaurar le mobilitate—ha essite tentate sin successo. Le operation a resection-angulation representa francamente le abandono de omne effortio de effectuar un reconstruction anatomic e se concentra super le restablimento del functiones del articulation coxal. Le operation consiste de duo bencognoscite manovras: (1) Resection del capite e cervice femoral pro restaurar le possibilitate de movimento sin dolor e (2) osteotomia angulational subtrochanteric del typo de Schanz, effectuate in le plano coronal pro restaurar le mobilitate. In 1943, le execution del operation in duo phases, usate depost 1934, esseva reimplaciate per un manovra a phase unic in que fix metallic al sito del osteotomia esseva util pro render possibile le precoce institutio movimento. Le manovra ha producit gratificante procentage de alleviament dolor e de melioration de motilitate. Ill applicabile in omne conditiones que i essa le articulation coxal, sin reguard pathologia subjacente. Es sublineate le portante de determinar accuratemente, le operation, le grado a que un abduc del osteotomisate fragmento distal del more pote esser effectuate, de maniera le angulo "post-osteotomic" non excede troppo le inclination del pariete exte ipsilateral del pelve.

Es describite le technica currentement uso e etiam le regime post-operatori pr patiente in qui le operation a resecti angulation ha essite effectuate.

25

Resection of Major Portion of the Calcaneus*

L. L. Wiltse, M.D.,† J. Gordon Bateman, M.D.,†
and Sidney Kase, M.D.‡

In this chapter we will describe an operation in which the greater portion of the calcaneus is resected. We will discuss the operative indications and present the case histories of 7 patients who have had the operation. Roentgenograms and photographs of some of the patients will be shown, and a table will be presented giving detailed facts about all the patients who underwent operation by this technic.

The first case was seen in 1947. This was:

Mr. B. R. (see table, p. 276), a young, white male, age 24, who for 3½ years had had hematogenous osteomyelitis of the calcaneus, which had developed secondary to an ischiorectal abscess. Five or 6 operations had been performed in an effort to stop the drainage, but to no avail. These included 2 or 3 sequestrectomies and about an equal number of incisions and drainages. He had been in and out of the hospital so much that he was completely unable to hold a job and was virtually a ward of the state. Whenever he tried to be on the foot for any length of time and work, the foot would swell, and cellulitis would develop. Then it would be necessary for him to go back into the hospital for elevation, antibiotics and hot packs.

In considering what to do for this man, it was felt that there was no further use in attempting sequestrectomies We were aware of the Gaenslen[2] operation but felt that it would not be adequate in this case. At about this time reports were appearing in the literature regarding total removal of the calcaneus with apparently good results. Pridie, in England,[3] in particular had reported total removal in 15 patients, with good results in most cases. There were several other sporadic reports of single cases of total excision of the calcaneus, usually for tumor or tuberculosis. Cleminson[1] reported a case of total removal for severe fracture, with good results. However, in checking a very few cases of total removal that we could find, it seemed that occasionally a rather severe deformity resulted; therefore, the operation that is to be described was done, and the result was remarkably good.

We talked with this patient 3 weeks ago 11 years after operation. He is now working a full 8-hour day on his feet, he is unaware of any limp, and he has no pain. That foot does tire a little toward the end of the day. There has been no drainage since operation, and the patient has not been hospitalized since. He can rise up on tiptoe on the side that underwent operation and can run satisfactorily. Part of the time he wears a lift that was fitted for him, but it seems to make no difference whether or not the lift is in his shoe. (See Figs. 1-3.)

Since 1947, when the first calcaneus operation was done, we have had occasion to repeat this operation on 6 more patients. In each case, although the indication has varied, the technic of the operation has been essentially the same, and the results have been uniformly excellent.

OPERATIVE TECHNIC

The patient is placed on his abdomen, with a large sandbag under the anterosuperior iliac spine on the side to undergo operation. The incision begins just in front of, and about an inch proximal to, the insertion of the tendo achillis and extends forward to the inferior tip of the calcaneocuboid joint. This is carried down to the

* Read at meeting of The Association of Bone and Joint Surgeons held in Palm Springs in 1958.

† Long Beach, Calif.
‡ San Bernardino, Calif.

FIGS. 1-3, Case 1 (see table, p. 276). Fig. 1. Roentgenogram before operation of a case of hematogenous osteomyelitis of the calcaneus.

bone. By sharp dissection the soft tissues are removed from the calcaneus in the area distal to the incision. Likewise, the tendo achillis is cut off with sharp dissection. The peroneal tendon sheath does not have to be opened, but the anterior end of the incision comes very close to the sheath. The calcaneocuboid joint and the subastragalar joint are not opened; therefore, infection does not spread into these joints. With a wide thin

FIG 2. (*Left*) Roentgenogram taken 11 years after resection of the calcaneus.

FIG 3 (*Right*) Photograph taken 11 years after resection of major portion of the calcaneus. Note that the patient can stand well on tiptoe.

osteotome, the calcaneus is cut through on a line beginning just below the inferior tip of the calcaneocuboid joint, extending backward and slightly upward, remaining about ¾ inch below the subastragalar joint. This mass of bone is grasped in a large towel clip, and, with sharp dissection, removal is completed. Using rather fine chromic catgut, the tendo achillis is sutured to the plantar fascia with 3 or 4 sutures, and the skin is closed loosely. A pressure dressing then is applied with an Ace bandage. A plaster splint is put over the Ace bandage, the foot being allowed to drop down into equinus so that the tendo achillis may get a distal attachment. The splint extends from below the knee to the tip of the toes. (See Figs. 4-6.)

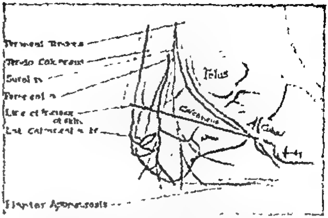


Fig. 4. Shows the line of incision on lateral side of foot, with underlying structures shaded in. No difficulty is experienced in removing bone through this incision.

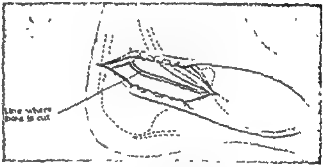


Fig. 5. Shows line where bone is cut through.

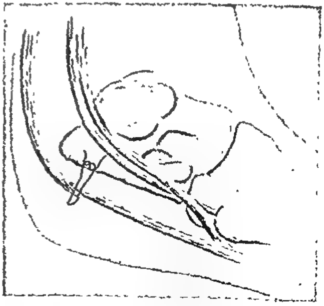


Fig. 6. Tendo achillis is sutured to plantar fascia.

POSTOPERATIVE CARE

The patient is allowed up on crutches, and at the end of 6 weeks the splint is removed. Sutures may be taken out in 3 or 4 weeks. It is wise to leave them in an extra long time, as this thick and frequently scarred skin heals rather poorly. In many of our cases we left the stitches in the full 6 weeks. We use a fine grade of cotton suture for the skin, and very little maceration occurs. At the end of 6 weeks the patient goes without a splint but walks with crutches, limbering up the foot. At about 8 weeks after the operation he begins to put weight on his foot and gradually discards his crutches.

INDICATIONS

There are 2 types of cases in which the operation is indicated:

1. Osteomyelitis of the Calcaneus

Four of our cases were done for osteomyelitis of the calcaneus. There are still quite a few patients with fractured legs who are treated by pin traction through the calcaneus, and these do occasionally become infected. Also, occasionally, fractures of the calcaneus are treated by pins or open surgery, and these also may become infected. In the case of pin-traction infection, the

involvement usually is down in the cancellous portion of the calcaneus and is completely removed by this operation. Even in cases where the infection involves the whole calcaneus, the operation has been very effective. It is our belief that the more dense bone just below the subastragalar joint is less likely to harbor infection; therefore, by taking off the tuberosity, which is more cancellous, the disease is cured.

2. Intractable Ulcers on the Heel

We have seen chronic ulcers on the back or the undersurface of the heel in various situations. The following was the first case seen in which this operation was used.

Mr. H. S. (see table, p. 276), age 26, had had a serious motorcycle accident 8 years previously. Among other injuries, he had had a severe fracture of the left leg, with some nerve damage, that caused loss of sensation on the back of the calf and the back of the heel. All the injuries, including the fracture, had healed The nerve had regenerated, so that, when seen, he had normal sensation; but, while he had been in the cast, an ulcer had developed on the back of the heel. This ulcer was about the size of a silver dollar. *In the years since his injury he had* several operations in an attempt to get skin over this ulcer. These had been, first, a cross leg flap, which had necrosed; a tube graft, which had failed; and 2 split-thickness grafts. One of the split-thickness grafts apparently had taken partially but had broken down when he had started *wearing a shoe. He, too, was unable to hold a* job, because every time he tried to walk for a few days the ankle would swell and show signs of cellulitis.

When he came to us, he requested amputation because he had had this condition for 8 years and was anxious to have something definitive. The operation as described was done. The only variation in technic was that the ulcer was excised first. In excising the ulcer a circular incision was made around the ulcer, going clear

Figs. 7 and 8, Case 3 (see table, p. 276)

Fig 7 (*Top*). Roentgenogram taken 4 years after resection of calcaneus because of large ulcer on back of heel This seems to be about the ideal amount of bone to remove.

Fig. 8 (*Left*). Shows range of dorsiflexion and plantar flexion of ankle This patient has enough strength in plantar flexion to stand on tiptoe, putting all his weight on the foot operated upon.

Fig. 9, Case 4 (see table, p. 276). Good strength of plantar flexion demonstrated in 83-year-old male 7 years after resection of calcaneus.

Fig. 10, Case 5 (see table, p. 276). Ulcer on the heel of paraplegic treated by resection of calcaneus to gain skin.

down to the bone, and the tissue was peeled off the bone. Since the ulcer was infected, these instruments then were discarded, and gloves were changed after removing the ulcer. The incision next was extended around laterally to the inferior point of the calcaneocuboid joint. On closure, plenty of skin was available. The patient was in a splint for 6 weeks, on crutches for 2 weeks, then started weight-bearing. No drainage developed at any time.

He was seen a few weeks ago, 4 years postoperatively. Now he walks with no limp, can walk barefoot on concrete without pain, and is able to do a full day's work on his feet. He can walk on tiptoe and can rise on tiptoe without support on the foot operated upon. He can run quite normally. He has a well-healed lateral scar and ½ inch of shortening when measured by leveling the iliac crests. He is holding a regular job and is completely rehabilitated. (See Figs. 7 & 8.)

The fact that this man has only ½ inch of shortening was surprising at first, but the explanation was found in one patient who was extremely flat footed before surgery; he had no shortening whatsoever after surgery, because he was already walking in the center of his foot. He needed a lift under his heel postoperatively and did not get along well without it.

Paraplegics are prone to develop ulcers on the back of the heel. Figure 10 shows such a case treated by resection of the major portion of the calcaneus, with an excellent result.

Diabetics also occasionally develop an ulcer on the back of the heel. Case 7 was a 66-year-old woman with severe diabetes. When first seen she had marked circulatory loss in both legs. The oscillometer recorded a trace of pulsation in each calf. On the left heel there was an ulcer about the size of a silver dollar of several months' duration. Amputation was contemplated. Partial resection of the calcaneus was done, and, when the splint was removed 6 weeks later, complete healing was present. She developed excellent motion and a good pain-free heel. She then developed an identical ulcer on the opposite heel, and the same operation was done. Complete healing resulted in 8 weeks. No drainage ever occurred in either heel, and there was no loss of skin.

The table on page 276 gives in tabular form the 7 cases in which this technic was used.

Case 2 was seen at the County Hospital and was lost track of after 10 weeks. When last seen this woman was walking and had had no drainage since operation.

ADVANTAGES OF THIS OPERATION

Freedom from Pain. The patients whom we have seen over a long period of time have been remarkably free of pain.

Minimal Scar. The scar is off the weight-bearing surface, on the lateral side of the heel, and causes no particular trouble.

Case No	Patient	Age When Operated Upon	Disease	Duration of Symptoms	Length of Follow-up	Post-operative Drainage	Condition When Last Seen	Result	Figure
1	B R	24	Draining hematogenous osteomyelitis	3½ yrs.	11 yrs.	None	Walking well, no pain, no limp	Excellent	1-3
2	C. G.	32	Draining osteomyelitis from pin	3 yrs	10 wks.	None	Walking well, very little pain	Good, but follow-up too short	—
3	H. S	26	Ulcer on back of heel	7 yrs.	4 yrs.	None	Walking well, no pain, no limp	Excellent	7 & 8
4	F. F.	76	Draining osteomyelitis from operation for fracture	3 yrs.	7 yrs.	None	No pain on full weight-bearing	Excellent	9
5	L. F.	55	Ulcer in paraplegic	4 mos.	10 mos.	None	Excellent healing of ulcer	Excellent	10
6	F S.	55	Draining osteomyelitis from war wound	30 yrs.	8 mos.	None	Walking well, foot well healed	Good, still improving	—
7	E M.	66	Diabetic ulcers on both heels	4 mos.	4 mos. 2 mos.	None	Both feet completely healed, good motion in ankles and feet	Good, still improving	—

Flaps do not necrose. The incision being on the lateral side of the heel or, in the case of an ulcer, on the back of the heel and around laterally, there seems to be no danger of necrosis of the flap. It is true that one small artery is cut on the lateral side, but this causes no trouble. It is extremely important not to extend the incision around medially, as the medial calcaneal artery will be cut, and then the flap may necrose.

Infection clears up. In all our cases this operation has cleared up infection.

Convalescence Short. We have been keeping the patients off the foot for 8 weeks.

Small Amount of Shortening. The maximum was ½ inch in our cases.

Little Danger of Cutting Important Structures. The technic is simple and easy to perform.

The subastragalar or the calcaneocuboid joints are not entered. Because of this, the danger of spreading infection to joints or tendon sheaths is minimal.

IMPORTANT POINTS IN PERFORMING THE OPERATION

1. Take out necessary amount of bone.
2. Suture loosely so that blood, which inevitably seeps from the bone, can get out through the suture line.
3. Splint in equinus. No effort is made to suture the tendo achillis to the bone, since this would complicate the procedure and possibly predispose to infection. The tendo achillis apparently grows solidly to the raw undersurface of the calcaneus.
4. Use antibiotics before and after operation in infected cases.
5. Do not take out sutures for several weeks. Often this skin is scarred and the circulation sometimes poor, and there is no need to take out the sutures soon.

COMPARISON WITH TOTAL RESECTION OF THE CALCANEUS

We have had no experience with total resection of the calcaneus. We have talked with a few surgeons who have. Reports vary. One of the chief criticisms is that in total resection the midtarsal joint occasionally turns and the foot goes into severe valgus. In the operation that we are presenting, this does not occur because the calcaneocuboid joint has not been disturbed, and the general shape of the foot remains remarkably normal.

CONCLUSION

There has been presented an operation that has proved to be very useful in 2 types of cases:

1. Osteomyelitis of the calcaneus.
2. Intractable ulcer on the back of the heel.

We have used it generally as a salvage procedure, since several of the cases came to us requesting amputation. The results have been so good that perhaps its use could be extended to other types of cases.

REFERENCES

1. Cleminson, K.: Excision of the calcaneus for fracture, J. Bone & Joint Surg. 34B: 158, 1952.
2. Gaenslen, F. J.: Split heel approach to osteomyelitis of the calcaneus, J. Bone & Joint Surg. 13:759, 1931.
3. Pridie, K. H.: Surg., Gynec. & Obst. 82: 671-675, 1946.

Resection de un Portion Major del Calcaneo

Summario in Interlingua

Le autores describe un operation per que le portion inferior ■ major del calcaneo es resectionate. Illo es effectuate via un incision lateral. Le calcaneo es secate transversemente, in un linea ab le puncto inferior del articulation calcaneocuboide in retro, circa tres quarte pollices infra le articulation subastragalar. Le portion inferior es re-

movite per dissection acute. Le tendine de Achilles es suturate al fascia plantar, e le pelle es claudite laxemente. Le pede prende le position de talipede equin, e un bandage de pression es applicate. Le patiente porta un ferula durante sex septimanas e comencia ambular post octo septimanas.

Quatro casos de osteomyelitis chronic del calcaneo ha essite tractate per medio de iste operation. In omne caso, le osteomyelitis esseva curate completemente. Le caso le plus ancian ha dece-un annos de observation post-operatori.

Un secunde indication pro le operation es ulcere intractabile al dorso del calce. Duo tal casos esseva operate con curation del ulcere a causa del abundantia de pelle obtenite per le elimination de osso.

Le patientes marcha remarcabilemente ben. Le duo con le plus longe observation post-operatori es libere de claudication; illes pote star super le puncta del pede, illes pote currer, illes es regularmente empleate, illes es sin dolor, e depost le operation illes ha habite nulle drainage.

26

Absolute Fixation With Contact Compression in Hip Fractures

(A New Fixation Device)

WILLIAM M. DEYERLE, M.D.*

The history of improved results in fractures is related to improved reduction fixation and contact compression.[5,9,11] When closed reduction and traction and plaster fixation were used, the percentage of good results was approximately 50 per cent.[20,21]

With the introduction of internal fixation, such as the Smith-Petersen nail and Moore pins, the good results were increased to approximately two thirds of the cases.[4] When we improved our reduction, as suggested by McElvenny,[13] and improved our fixation by attaching the Smith-Petersen nail to the shaft of the bone,[8] the results approached 80 per cent good results. I am proposing that we add absolute fixation and contact compression to improve results further.

WEAK POINTS AND COMPLICATIONS OF FIXATION TECHNICS COMMONLY USED

1. Failure to obtain adequate valgus reduction.

2. If the fixation apparatus is not anchored firmly to the shaft of the femur, it may work loose at the shaft end as well as at the head end.

3 If a one-piece Jewett style nail or Smith-Petersen nail with a Thornton attachment is used, fixation in the shaft is adequate; but then one must compromise by leaving the nail ½ to ¾ of an inch short of the cortex of the head to allow for absorption and, admittedly, accept less fixation of the head. One may elect to place the fixation well into the head cortex and attain firmer fixation, but, if absorption takes place with any motion at the fracture site, the nail will extrude into the joint. If the head cortex is hard enough, it may cause distraction at the fracture site as hyperemic decalcification and shortening take place distal to the fracture. A sliding triflanged nail will not control rotation.

4. A Smith-Petersen nail ½ inch in diameter cannot control the torsion and rotation associated with hip motion during the convalescent period. Actually the nail may cut out. Even when the nail does not cut out, the torsion and rotation motions at the fracture site are largely responsible for the hyperemic decalcification and shortening of the neck. This also causes injury to budding blood vessels and increases the fibrous tissue barrier to future blood vessels.

5. The multiple-pin technic of Moore, using Moore pins, has the threaded end in the shaft and the smooth end in the head. There is a natural tendency for the smooth end to cut into the head, and there has been no way up till now of fixing adequately the

* Department of Orthopaedic Surgery, Medical College of Virginia, Richmond, Va.

shaft end of the fixation to the femoral shaft and maintaining a preselected angle.

6. There has been no effort at maintaining contact compression with weight-bearing.

Approximately one third of the fractures of the neck of the femur develop avascular necrosis. The percentage of avascular necrosis in cases of nonunion is approximately 80 per cent. If these cases were broken down to include delayed union, I believe that approximately 90 per cent of the cases of avascular necrosis occur in those cases with a delayed union or nonunion. Many writers (Sherman, Phemister, Compere and McElvenny) considered delayed union and nonunion important factors in causing aseptic necrosis.

WHY IS THIS FRACTURE UNSOLVED?

The head of the femur has a notoriously precarious blood supply[6,10,17,19] and in many cases is avascular at the time of fracture. Many surgeons refuse to alter their technic or expect better results because they feel that they are dealing with an attenuated or inadequate blood supply. *The fact that the head is potentially avascular or totally avascular makes it all the more imperative to obtain an adequate reduction, maintain absolute fixation and promote early union.* Many excellent centers reporting a high percentage of poor results[3,4,15,17] create an air of complacency. The fascination of a new operation and an artificial head have taken the place of enthusiastic efforts at obtaining a bony union early. At the earliest sign of nonunion or avascular necrosis there is a strong tendency for the surgeon to abandon the head in favor of a metallic substitute. In some cases it is removed primarily. Doctor Dickson's review[7] and the reports of others[21] encourage a more alert attitude toward a difficult fracture.

PATHOLOGIC PHYSIOLOGY OF FRACTURE REPAIR IN THE HIP

The first 6 months the head will maintain its structure, even without a blood supply. One rarely sees any change in the trabeculae of the head in the first 6 months, even though a nonunion may show up prior to this time. In those cases that go on to a definite avascular necrosis, changes in the head before 6 months are minimal. The head may appear to be more dense, but this is due to hyperemic decalcification in the neck. In the more difficult cases blood-vessel buds must grow into the head from the fracture and the periosteum *distally*.[2,6,16,17,19] *The vulnerable point in a fracture during the first 6 months is not the head but the fracture line.* These growing blood vessels must

REPORTED MINOR COMPLICATIONS IN FRACTURES OF THE NECK OF THE FEMUR

Series	No.	Total Avascular Necrosis	Avascular Necrosis Union	Avascular Necrosis Nonunion
Nystrom[15]	120	25%	23%	70%
Compere *et al*[6]	21 (dogs)	38%	29%	78%
Phemister[17]	49	65%	13%	87%
Boyd and George[4]	300	33.6%		
Santos[18]	7 (pathologic specimens)		30%	70%
Boyd[3]	177	37%	32%	59%
Speed[20]	100	34%	8%	63%

be protected until union occurs.[6,16,17,19,21] Any motion,[6] particularly shearing and rotational motion, damages these blood vessels and causes a hyperemic decalcification of that portion of the fracture line with a blood supply, the distal side. This hyperemic decalcification causes shortening of the neck and additional loss of fixation with disruption of the fracture.[21] The damaged blood vessels lay down an area of fibrotic scar tissue that prevents additional blood vessels from growing across the fracture line.[21]

Absolute fixation prevents damage to budding blood vessels and minimizes the fibrotic barrier to additional new vessels. It also prevents torsion and thereby decreases any tendency toward hyperemic decalcification in the distal fragment.[21] Since there is little if any shortening of the neck and the fixation device allows for contact compression, this stimulates early union and allows the maximum opportunity for revascularization of the head.

Any shortening of the neck indicates motion at the fracture site and results in delayed union.

MECHANICAL FACTORS

1. The fracture may be an unfavorable angle, such as Pauwels' Type III.
2. The pull of abductors against an offset weight-bearing line places 600 pounds' pressure on the normal hip in walking.[1,10]
3. Load tolerance:
   - A. Normal hip—1,930 pounds
   - B. Fractured hip
     - a. Smith-Petersen nail — 350 pounds
     - b. Eicher prosthesis inserted in the femur—520 pounds[14]
     - c. Five threaded pins ⅛-inch in diameter inserted in the Deyerle plate—1,072 pounds.
4. Torsion, however, is not measurable; obviously, the radially placed multiple pins have more fixation than the single nail. If one is attempting to stop a spinning wheel, pressure at the hub requires considerable friction. If a small amount of pressure is applied at the perimeter, the wheel is stopped easily. Having the threaded pins distributed over a 1-inch radius in the head cortex distributes the strain much better than the triflanged nail. There is less pressure necrosis around this widely dispersed fixation.
5. Any fixation technic must allow for contact compression and still maintain a preselected angle with the shaft of the femur. Absolute fixation must prevent motion of the following types: Torsion, sliding, shearing, twisting, angulating. But it must allow for a continuous contact compression at the fracture site.

Absolute fixation is obtained by the author with pins threaded deep into the cortex of the head, just below the joint surface. They are spaced radially to prevent rotation, are inserted accurately, and are held in a preselected angle (140°) by a plate-and-guide combination. This allows for absolute fixation of the shaft end. Cruciate head pins are used for ease of insertion. Smooth shafts allow for sliding of the pin in the shaft portion and maintain contact compression without loss of reduction or position.

On roentgenograms the amount of fixation used has caused the erroneous impression that the neck is filled with hardware and there is no space for blood vessels. The area of the smallest portion of the average neck is approximately 1 square inch. The conventional Smith-Petersen nail occupies 1/16 square inch of area, or 4.8 per cent of the neck. Five pins ⅛-inch in diameter occupy 6/100 (.06) square inch, or 4.8 per cent of the neck. Eight pins occupy .0984 square inch or 7.7 per cent of the neck. Five pins and a Smith-Petersen nail occupy slightly more than 1/10 square inch, or 10 per cent of the neck. Eight pins and a Smith-Petersen nail occupy .1601 square inch, or 13 per cent of the neck (Fig. 1).

In established cases of nonunion and aseptic necrosis, Bonfiglio obtained a high

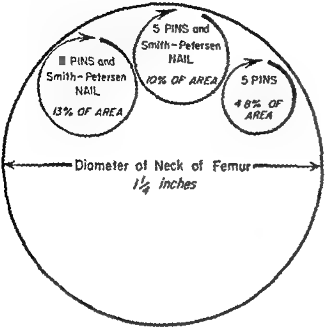


FIG. 1. Area chart of neck of femur showing area required by various fixation devices.

percentage of revascularization of the head by inserting 2 1-cm.-square cortical grafts occupying .3136 square inch, or 25 per cent of the neck. It is fairly well established that cortical bone graft is as resistant to blood vessels initially as metal.[3] The average fixation is 5 pins and a Smith-Petersen nail, occupying 10 per cent of the diameter of the neck. I believe that this compares favorably with the 25 per cent of the diameter of the neck occupied by Bonfiglio's cortical grafts. I am obtaining absolute fixation at the expense of 10 per cent of the diameter of the neck and leaving the other 90 per cent free for any budding blood vessels to grow into the head.

PREOPERATIVE CARE

It is felt that all hips should be reduced and fixed with absolute fixation. If the patient is in poor condition ... rs, and possibly 48 hours, may ... in traction for indicated digit... other supportive measures. ... our policy that the worse th... the patient, the more imperat... the hip fracture and restore ... tively normal activity (within the limits of his abilities prior to the fracture). We prefer local anesthesia supplemented by Pentothal or 5 per cent alcohol as needed.

PREFERRED TECHNIC FOR PLATE NO. 3 AND PINS IN NECK FRACTURES

In fractures at the neck it is imperative to obtain an adequate valgus reduction with impaction. Any spike or spur on the head must be overreduced so that it rests on the calcar femorale. This reduction can be accomplished satisfactorily only with the use of a fracture table with the legs in wide abduction. After overreduction is obtained, traction is released on the unaffected leg in such a way as to allow the head to roll over the neck. At the time that this is released, heavy impaction is obtained by a strong blow on the greater trochanter. Internal rotation sufficient to place the neck parallel to the floor is usually obtained when the foot is almost parallel to the floor. A roentgenogram obtained at this time would show the neck portion of the femur running smoothly into the shaft with very slight evidence of the prominence of the lesser trochanter.

A lateral incision approximately 8 inches long exposes the lateral shaft of the femur. Dissection is carried along the upper border of the shaft onto the neck, the capsule being dissected backward from the neck to allow palpation of the cephalad border of the neck and the distal border of the neck. With deep pressure toward the head, the general outline of the head can be felt

For purposes of description and illustration, the holes in the head of the plate will be designated as follows, with the plate placed ... shaft as shown in Figure 2A: Th... phalad holes and 3 distal holes. ... these 3 holes at each end of the ... y is an anterior hole, and ... posterior hole. In the center ... 2 slightly offset center holes.

As ... re 2A ... 3-inch

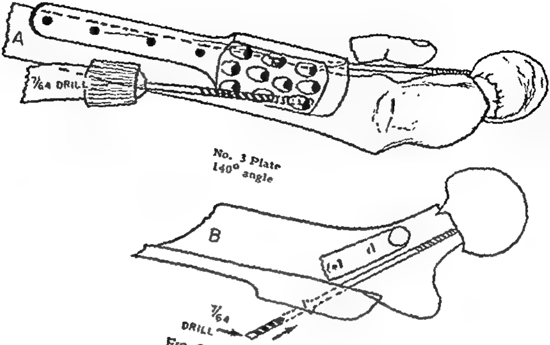


FIG. 2. See text.

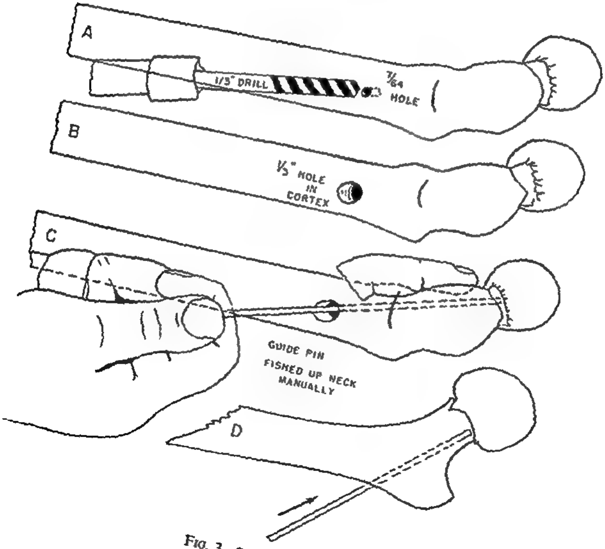


FIG. 3. See text.

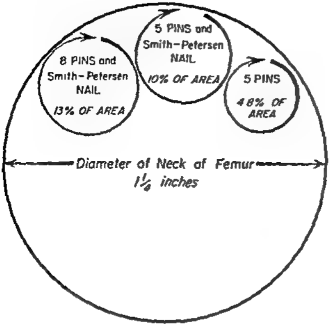


FIG. 1. Area chart of neck of femur showing area required by various fixation devices.

percentage of revascularization of the head by inserting 2 1-cm.-square cortical grafts occupying .3136 square inch, or 25 per cent of the neck. It is fairly well established that cortical bone graft is as resistant to blood vessels initially as metal.[3] The average fixation is 5 pins and a Smith-Petersen nail, occupying 10 per cent of the diameter of the neck. I believe that this compares favorably with the 25 per cent of the diameter of the neck occupied by Bonfiglio's cortical grafts. I am obtaining absolute fixation at the expense of 10 per cent of the diameter of the neck and leaving the other 90 per cent free for any budding blood vessels to grow into the head.

PREOPERATIVE CARE

It is felt that all hips should be reduced and fixed with absolute fixation. If the patient is in poor condition, 24 hours, and possibly 48 hours, may be allowed in traction for indicated digitalization and other supportive measures. In general, it is our policy that the worse the condition of the patient, the more imperative it is to fix the hip fracture and restore the patient to relatively normal activity (within the limits of his abilities prior to the fracture). We prefer local anesthesia supplemented by Pentothal or 5 per cent alcohol as needed.

PREFERRED TECHNIC FOR PLATE NO. 3 AND PINS IN NECK FRACTURES

In fractures at the neck it is imperative to obtain an adequate valgus reduction with impaction. Any spike or spur on the head must be overreduced so that it rests on the calcar femorale. This reduction can be accomplished satisfactorily only with the use of a fracture table with the legs in wide abduction. After overreduction is obtained, traction is released on the unaffected leg in such a way as to allow the head to roll over the neck. At the time that this is released, heavy impaction is obtained by a strong blow on the greater trochanter. Internal rotation sufficient to place the neck parallel to the floor is usually obtained when the foot is almost parallel to the floor. A roentgenogram obtained at this time would show the neck portion of the femur running smoothly into the shaft with very slight evidence of the prominence of the lesser trochanter.

A lateral incision approximately 8 inches long exposes the lateral shaft of the femur. Dissection is carried along the upper border of the shaft onto the neck, the capsule being dissected backward from the neck to allow palpation of the cephalad border of the neck and the distal border of the neck. With deep pressure toward the head, the general outline of the head can be felt.

For purposes of description and illustration, the holes in the head of the plate will be designated as follows, with the plate placed upon the shaft as shown in Figure 2A: There are 3 cephalad holes and 3 distal holes. In between these 3 holes at each end of the plate superiorly is an anterior hole, and inferiorly is the posterior hole. In the center of the plate are 2 slightly offset center holes.

As shown in Figure 2A and B, a 3-inch

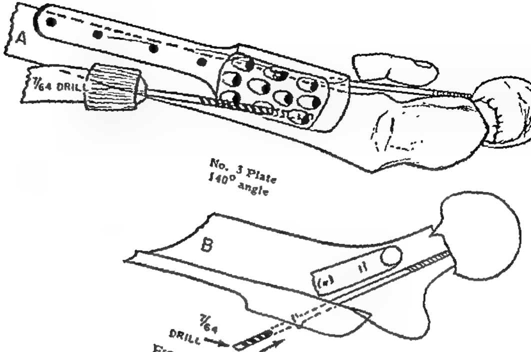


Fig. 2. See text.

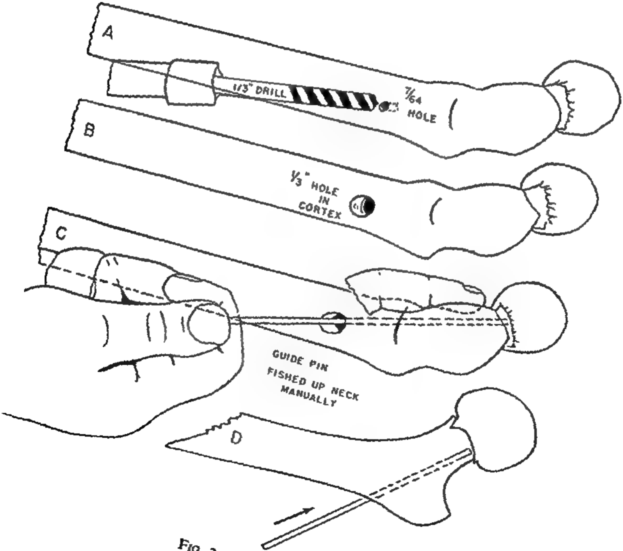


Fig. 3. See text.

fixation pin is placed in the anterior hole and is guided along the neck until it points approximately to the center of the head. This alignment is determined by a palpating finger. The shaft then is held parallel to the shaft of the femur, with the pin held pointing toward the center of the head running parallel to the neck and the plate held acting as a guide. A 7/64-inch drill hole is made, using the posterior hole as shown in Figure 2A and B to drill this hole. This will place the hole in the exact line with the guide pin running superior to the neck. The 7/64-inch hole, which has been oriented to the 140° angle plate in this fashion, then is enlarged to 1/3-inch hole, a drill being used. It is advisable to have 2 ⅛-inch pins of equal length to use as guide pins. These may be threaded or plain. With the palpating finger superior to the neck, the ⅛-inch pin is fished up the neck manually, as shown in Figure 3C and D. If it is placed in the neck in this fashion, the cortex of the neck acts as a confining tube to direct the pin into the head. It is not necessary or desirable to have the guide pin go into the head. Roentgenograms are taken in 2 views to determine the exact position of the guide pin in reference to the head and the neck. If the guide pin is cephalad in the neck, the

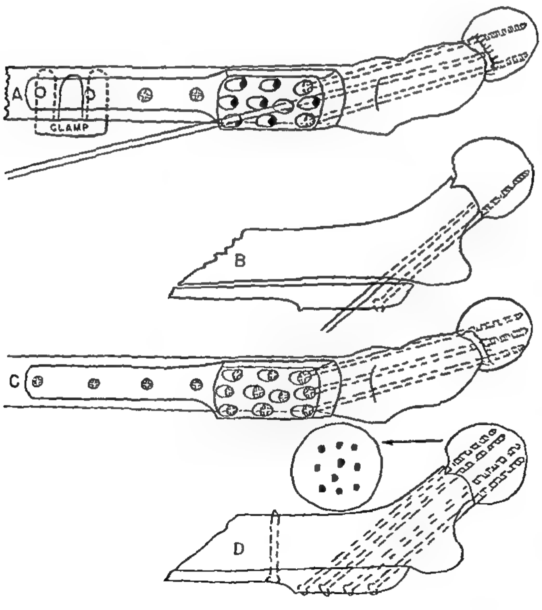


FIG. 4 See text.

appropriate hole in the plate is placed in the guide pin to place the maximum number of parallel pins in the head disregarding the neck. Usually this will have the guide pin extending through the more cephalad of the 2 center holes. If the guide pin were shown on roentgenogram to be distal, one of the more distal center holes would be used and placed over the guide pin. The plate is clamped to the shaft of the femur over the guide pin.

The proper-length pins can be determined by measuring the length of the guide pin extending toward the head and adding sufficient length to go well into the cortex of the head as near the joint as possible. It is helpful prior to surgery to set up a nail with pins of estimated length by examining the roentgenograms, and these are very accurate. The use of the guide-pin estimation acts as a double check on the length. Once the proper pin length for any hole is selected, the remaining holes have a constant relationship. This relationship is as follows: The usual length of the pin required in the 3 cephalad holes is 4 inches. In that event, the anterior and posterior hole would be 4½ inches, as would the more distal of the 2 center holes. The 3 distal holes would be 4¾ inches. This leaves the cephalad of the 2 central holes unaccounted for. This hole will take a pin ¼ inch longer than the cephalad holes, or 4¼ inches. The general relationship is constant. The 3 cephalad holes are ½ inch shorter than the anterior and posterior hole and the distal central hole. The anterior and posterior hole and the distal central hole are ¼ inch shorter than the 3 distal holes. The cephalad of the 2 central holes is ¼ inch shorter than the hole immediately distal to it and ¼ inch longer than the hole immediately cephalad to it.

As shown in Figure 4A and B, with the clamp holding the plate tightly to the cortex over the guide pin, a long 7/64-inch drill is used to drill across the fracture site for easier insertion. As each of the Woodruff head ⅛-inch fixation pins is inserted, the leg is wobbled backward and forward, the foot being used as a lever in order to double-check to see that the acetabulum is not impaled. A Woodruff head screwdriver and hand drill or motor drill facilitates the insertion. When 2 or 3 pins are in place, the guide pin is withdrawn and the appropriate-length Woodruff head fixation pin is placed in the same hole. It is unimportant whether or not the pins leave the neck and return into the head; the important thing is that they lodge in the head. Figure 4C and D shows that all 10 pins may be placed in certain cases; however, 5 or 6 are sufficient to allow immediate weight-bearing. In neck fractures it is important that these 5 or 6 go right to the joint surface, in order that they impale hard cortical bone. In the

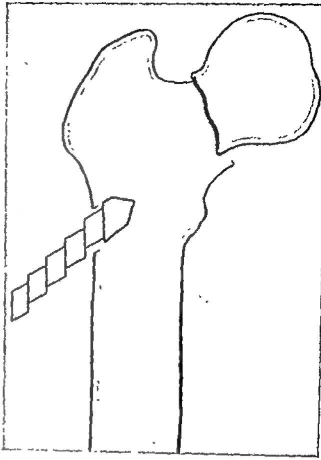


FIG. 5. Overreduce fracture on fracture table, the spike resting on calcar femorale. Roentgenograph. Drill ½-inch hole through lateral cortex *only*.

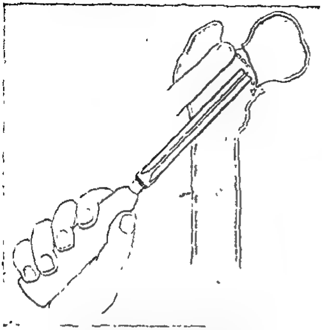


FIG. 6. Dissect enough to palpate neck anteriorly. Nail inserted manually through loose hold. Resistance of cortex guides nail up neck *to* fracture.

FIG. 7. After roentgenographic check (2 views), plate is bolted to nail and acts as guide for fixation pins. Plate available in varying angles

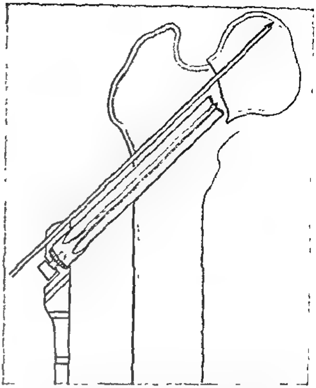


FIG. 8. Using one of superior holes, a ⅛-inch (or smaller) hole is drilled across lateral cortex. A long 6½-inch fixation pin is drilled through the plate and hole into the head to prevent tilting when the large nail is driven home.

more unstable intertrochanteric and peritrochanteric fractures, it may be desirable to attempt to place 7 or 8, or even 10, to immobilize as many comminuted fragments as possible and allow early weight-bearing. I have routinely inserted all 4 of the screws down the shaft of the plate, but in neck fractures it is entirely possible that 1 or 2 are sufficient. The plate may be sawed off or shortened to have only 1 or 2 screw holes in the shaft.

TECHNIC USING TRIFLANGED NAIL AND PINS

The fracture is reduced on the fracture table with adequate valgus reduction and impaction, as suggested by McElvenny (Fig. 5). Any available spike on the head is placed well down in the neck superior to the calcar femorale. Expose the upper shaft of the femur enough to palpate (with the finger) the superior and the inferior borders of the neck (Fig. 6). A ½-inch hole is drilled approximately 1 inch below the trochanter. This allows a Smith-Petersen nail to be fishtailed up the neck. If the nail is inserted manually an not hammered, the cortex of the nec the nail to the

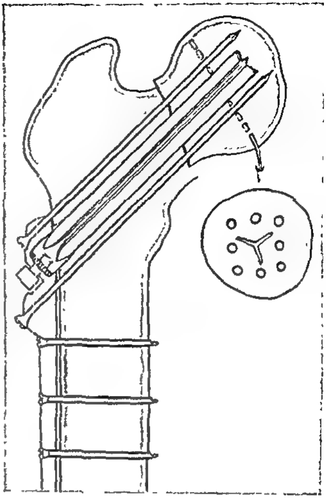


FIG. 9. The nail and the plate are driven into place, the end stopping ½ inch from cortex of the head. The fixation pins are related to the nail lengths as follows: 3 superior pins ½ inch longer, the 2 intermediate pins 1 inch longer, and the 3 inferior pins 1¼ inch longer. This places the threaded points in cortex of the head.

fracture site. When the nail approaches the fracture site, roentgenograms are taken in two views.

The No. 1 plate is attached to the nail with an Allen head screw. One or 2 long ⅛-inch fixation pins are inserted across the fracture into the head and may be inserted temporarily up into the acetabulum (Figs. 7 & 8). With this fixation to maintain the position, the nail and plate are driven in and attached to the shaft with 2 to 4 screws (Fig. 9). I prefer to have the nail ½ to ¾ inch short of the head cortex. This allows for any absorption that may take place and still does not prevent contact compression.

The threaded pins may be inserted with greater ease if the tract first is drilled with a long 7/64-inch drill.

The length of the threaded fixation pins

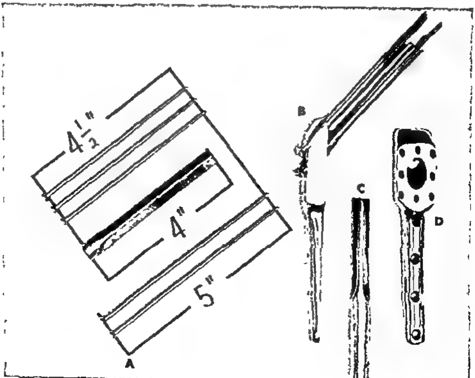


FIG. 10. (A) Selection of pin lengths. If Smith-Petersen nail is 4 inches long and driven to within ½ inch of head cortex, the 3 superior pins are ½ inch longer, the 2 lateral pins 1 inch longer. (B) 4-inch nail with 3 superior pins 4¾ inches, 2 lateral pins 5¼ inches, assembled in place. (C) Modified Smith-Petersen nail, round shank to allow for greater ease of sliding in lateral cortex and plate guide. (D) Alternate plate with .505 hole for sliding of Nail C. A cancellous graft may be used in place of the Smith-Petersen nail. (No. 2 plate)

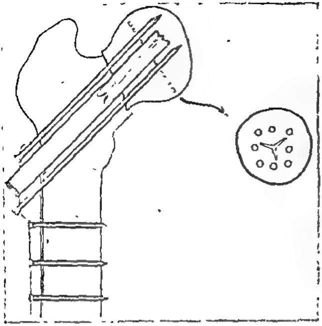


FIG. 11. Center nail with long shank driven to the cortex of the head which slides through the plate on compression.

FIG. 13. Smith-Petersen nail extracted partially to act as guide for placement of plate.

FIG. 14. Guide plate combination inserted over Smith-Petersen nail.

are directly related to the length of the nail (Fig. 10A & B). If a 4-inch nail is used, the superior 3 pins will be the length of the nail plus the distance from the tip of the nail to the head cortex. If the nail is 4 inches long, the superior 3 fixation pins selected will be 4½ inches in length. The 2 lateral fixation pins will be ½ inch longer than the superior 3, or 5 inches long. If any of the

FIG. 12. A 60-year-old male. Nonunion of 16 months' duration. The pin is in satisfactory position and is used to anchor guide and plate combination.

FIG. 15. Using the plate as a guide, a hole is drilled through the cortex of the trochanteric region, and a cruciate head fixation pin is drilled into place.

FIG. 16. The ½-inch drill is drilled through the guide plate up into the head (3 cruciate head fixation pins are in place).

3 lower fixation pins are used, they will be ¼ inch longer, or 5¼ inches long. Our usual fixation is a Smith-Petersen nail and 5 fixation pins. If there is a low nailing, which is customary, we use the 5 superior pins (Fig. 10B). If we have a high nailing, we use the 5 inferior pins. If it is slightly anterior, use the 5 posterior pins. If it is slightly posterior, use the 5 anterior pins. If one obtains a dead-center nailing, one may use all 8 pins. After all pins have been placed, they are tightened a half a turn, and this further impacts the fracture as there is a lag screw effect since the threaded portion is primarily in the head, the remaining portion of the fixation pins being smooth. We like to have the points of the threaded pins immediately under the joint (Fig. 9). Roentgenograms are taken in two views.

TECHNIC FOR TRIFLANGED NAIL OR BONE GRAFT

An alternate technic is to use a plate No. 2 with a .505 hole, which allows for the insertion of a modified Smith-Petersen nail (Fig. 10C & D). This Smith-Petersen nail may be placed completely in the cortex of the head, and it will slide distally with any contact compression (Fig. 11). This technic has the advantage of allowing for a very simple bone-grafting procedure at the earliest signs of nonunion or aseptic necrosis without disturbing any union that might be in

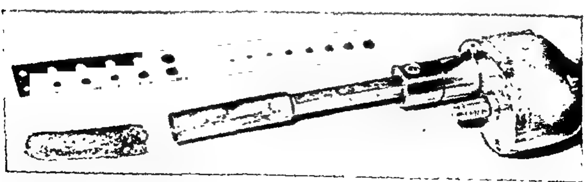


FIG. 17. Cancellous plug removed from anterior iliac crest with Stryker trephine with ½-inch inside diameter.

Fig. 18. The plug is driven through the guide plate across the fracture site well up into the head.

progress. The Smith-Petersen nail may be removed under local anesthetic and a ½-inch drill inserted across the plate, which now is acting as a fixation apparatus for the fixation pins and as a guide for the ½-inch drill. The drill is passed through the neck and into the head across the insipient non-union or aseptic necrosis (Fig. 16). Through a separate incision over the anterior iliac crest, a Stryker trephine oscillating plug cutter is used to remove a 2½-inch plug that has an outside diameter of slightly less than a half inch (Fig. 17). This is easily tapped across the fracture site (Fig. 18), and additional bone may be used to fill in the distal portion of the drill hole. If an unfavorable fracture is present, one may osteotomize in the subtrochanteric region to improve the weight-bearing line (Figs. 19 & 22).

POSTOPERATIVE CARE

We use neither narcotics nor barbiturates

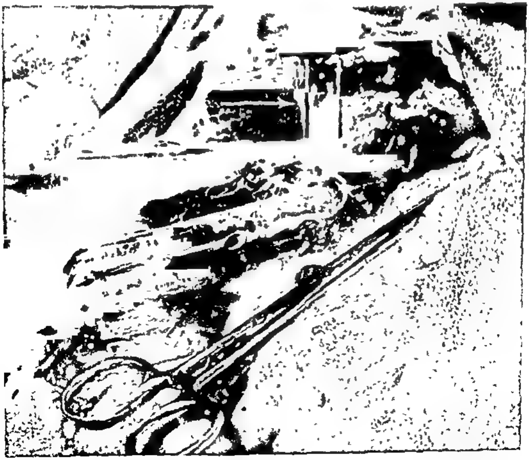


Fig. 19. Dickson or Blount type subtrochanteric osteotomy to correct angle 25°.

We feel that aspirin is adequate for relief of pain, and Benadryl is a sufficient sedative for sleeping at night. *The patient is started on weight-bearing within the first 3 to 5 days,* using a 4-point gait with crutches to prevent falling. He is encouraged to bear weight on the foot within the tolerance of discomfort. It has been amazing how little pain is experienced. A ¾-inch lift in the *opposite* heel places the center of gravity *toward the fractured hip and improves* abductor function. This decreases the strain on the fractured hip and improves the gait. Abduction exercises are stressed.

Fig. 20. Plate bolted to shaft.

TECHNIC FOR OLD-ESTABLISHED NONUNION WITH MALPOSITION OF THE HEAD

If the nail is in the proper position, it may be used as a guide (Figs. 12-14); if not, the plate is attached to the trochanteric region in such a way as to allow for 25° to 40° of subtrochanteric correction of the weight-bearing line. In an old-established nonunion, where there is malposition of the head, we osteotomize subtrochanterically in a modified Dickson fashion in order to place the head in a more favorable position with reference to the weight-bearing line. Occa-

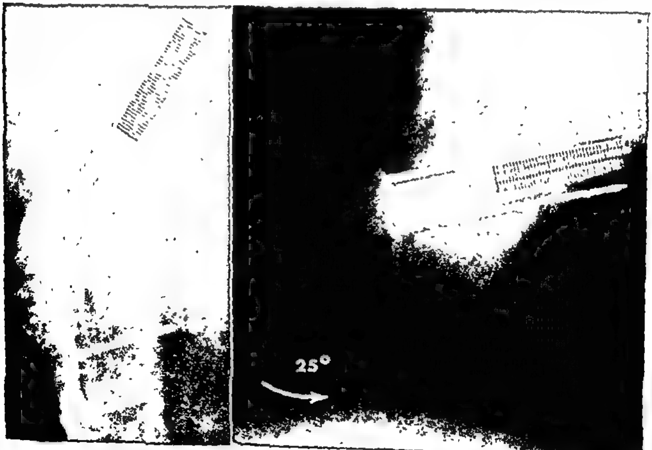


Fig. 21. Roentgenogram showing graft in place with driver behind it. Eight fixation pins in head (*right*). Driver removed. Subtrochanteric osteotomy allowing 25° correction of weight-bearing line (*left*). United at 10 months. Returned to work on railroad. (No avascular necrosis)

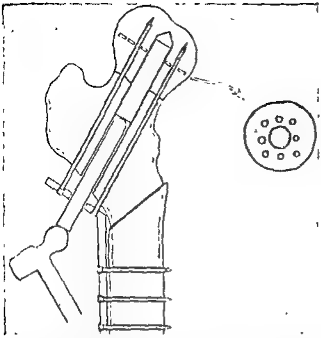


FIG. 22. Drawing of Blount-type osteotomy with graft. Plate with .505 center hole for drill and cancellous bone graft. Subtrochanteric osteotomy improves weight-bearing line.

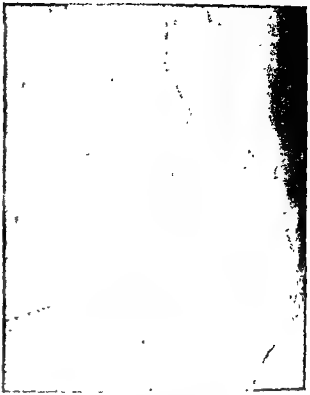


FIG. 24. Valgus reduction; impacted superior portion of neck; slight distraction inferior portion of neck; 3 months.

FIGS. 23-27. Fracture neck in patient aged 62. FIG. 23. Unfavorable angle.

FIG 25 (*Right*) Six ⅛-inch fixation pins and Smith-Petersen nail Notice trabeculae across fracture site. Patient has been walking since third day There was early bone union.

Fig. 26. At 8 months: fixation removed; new bone deposited on pin tracks; absorption of bone in head; evidence of a blood supply in head. Notice that there has been no change of position since reduction (Fig. 23). Patient has been walking since third day. Solid bony union.

Fig. 27. At 8 months, lateral view. Note new bone along pin tracks, vasculosis in head and solid bony union. Pins removed to obtain roentgenogram. No complaint of pain. Walking with cane.

sionally one may correct this as much as 45°. If the nail is in the proper position, it may be used as a guide for the attachment of the plate and simplifies the procedure (Figs. 12 & 13). The plate is placed over

Fig. 28. Intertrochanteric fracture in patient age 80. Walking since third day; solid bony union at 4 months; no pain or tenderness over hip area; full hip motion; walking with cane.

FIGS. 29 and 30, Negro male, age 14.
Fig. 29. Slipped epiphysis.

FIGS. 31 and 32, same patient. Fig 31. Neck fracture 3 months after operation. Old-style pins threaded in the shank and plain at point cut into hip. The patient fell and sustained the subtrochanteric fracture. The neck fracture was not disturbed.

the partially extracted nail (Fig. 14). One fixation pin is inserted across the fracture into the head, and even into the acetabulum if necessary (Fig. 15). This avoids disturb-

FIG. 30. Five months after operation. A ½-inch cancellous graft into head Five fixation pins inserted through guide plate. No reduction attempted Excellent motion, walks with very slight limp, weight-bearing started at 4 months

ance of the fracture site. With this fixation pin in place, a ½-inch drill is placed in the Smith-Petersen nail track through the plate and drilled well across the fracture site up into the head (Fig. 16). The drill is left in place to avoid any of the threaded pins encroaching upon the space to be filled by a graft later. The remaining fixation pins are drilled in with a cruciate head screwdriver. After 5 to 8 fixation pins are properly placed with the points in the region of the cortex, the drill is removed. A 3-inch cancellous plug slightly smaller than ½ inch in diameter is removed from the anterior iliac crest with a Stryker trephine cutter (Fig. 17). It is tapped into the head (Fig. 18). One may also use additional chips to fill up the remaining portion of the drill track after the cancellous plug is placed across the fracture site. A subtrochanteric Dickson osteotomy then is performed (Fig. 19), and the plate is screwed to the distal shaft (Fig. 20) to improve the weight-bearing line 25° to 40° (Figs. 21 & 22).

In 10 days a single spica is applied from the nipple line to the ankle on the affected side. This is applied in 10° flexion and 10° abduction. The patient is allowed to walk on crutches with partial weight-bearing on the affected limb. It is not felt that weight-bearing would be harmful to the fracture site but the subtrochanteric osteotomy is difficult to hold with full weight-bearing. We want approximately one third weight-bearing on this limb to stimulate union and maintain contact compression.

FIG. 32. The pins were shortened, and a longer plate was attached. We now use pins threaded 1 inch from the point with cruciate heads and plain shank.

TYPICAL CASES

NECK FRACTURE (2-Year Follow-up)

Female, age 62. Neck fracture (Figs. 23 & 24) fixed with a Smith-Petersen nail and 8 fixation pins. The patient was walking on the third day. She could walk without crutches but was advised to walk with a 4-point gait. At 3 months, union was well in progress with trabeculae across the fracture area (Fig 25). At 8 months, pins were removed and revealed new bone deposited on pin tracks and absorption of bone in the head, indicating the presence of a blood supply (Figs. 26 & 27). Once solid union is present, to remove the pins may help in further revascularization of the head. If the pins are turned in and at the same time extracted forcefully, the threads will grind out the fibrous tissue lining of the pin track and expose areas of the head to increased blood supply. The Smith-Petersen nail track may also be curetted for the same purpose.

INTERTROCHANTERIC FRACTURE (Fig. 28)

Female, age 80. This woman was walking on the third day. There was solid bony union at 4 months with no displacement. Pins may be removed if symptoms indicate.

SLIPPED EPIPHYSIS (Fig. 29)

Guide placed around drill after 1 or 2 fixation pins held the guide in place. A ½-inch drill across the epiphysis with no effort at reduction. A ½-inch cancellous bone plug was inserted. Five fixation pins were drilled across the plate. The patient was walking on crutches at the end of 3 weeks but not bearing weight on the affected limb. This man had an excellent result at 7 months with very little limp and no sign of joint narrowing. The epiphysis appears to be closed (Fig. 30).

COMPLICATIONS

In one case, using the old-style pins threaded at the shaft end and not threaded in the head, the pins cut into the acetabulum, and, although this woman was walking, she had a definite limp, and it is felt that the limp caused her to fall. It is interesting to note that she did not disrupt the initial fracture site when she fell at 3 months but did sustain a fracture in the subtrochanteric region (Fig. 31). This necessitated shortening of the pins and application of a long plate (Fig. 32). (The patient was not allowed to walk following this second procedure because of the subtrochanteric fracture.) We now use routinely the pins threaded only in the head portion of the pin. There has been no shortening or loss of position in any other case. This is the only case of loss of fixation or shortening of the neck.

RESULTS OF 30 CASES

20 fresh fractures, neck
 7 fresh fractures, intertrochanteric
 1 slipped epiphysis
 7 intertrochanteric fractures
  All united, excellent positions
 1 slipped epiphysis
  Excellent result
 2 old nonunions (14 months)
  8 pins and cancellous bone graft
   (Solid union, 8 months)
  Rotation osteotomy

20 neck fractures
 4 died
  2 at 3 months
  2 at 14 months
 16 united (1 to 2 year follow-up),
  no avascular necrosis

Three of the neck fractures that died were in the 85 plus age group; 2 had strokes prior to nailing.

SUMMARY

The controllable factors in hip fractures are:

1. Adequate valgus reduction on a fracture table.
2. Contact compression at the fracture site.
3. Absolute fixation to maintain 1 and 2 above.
4. A method of treatment that accomplishes these is presented.

DEYERLE PLATES

Any of the three plates can be obtained from Price-Filler Machine Company, 508 Rorer Avenue, S. W., Roanoke, Va. The fixation pins and the plates are available at Zimmer Manufacturing Company, Warsaw, Ind., and Richards Manufacturing Company, Memphis, Tenn. Acme Manufacturing Company, in Greensboro, N. C. also makes the fixation pins.

REFERENCES

1. Blount, W B.: Don't throw away the cane, J. Bone & Joint Surg. 38A:695, 1956.
2. Bonfiglio, Michael: Aseptic necrosis of the femoral head in dogs: effect of drilling and bone grafting, Surg., Gynec. & Obst. 98: 591, 1954.
3. Boyd, H. B.: Avascular necrosis of the head of the femur, Am. Acad. Orthop. Surgeons, Lect 12:196-204, 1957.
4. Boyd, H. B., and George, I. L.: Complications of fractures of the neck of the femur, J. Bone & Joint Surg 29:13-18, 1947.
5. Charnley, John: Compression Arthrodesis, Edinburgh, Livingstone, 1953.
6. Compere, E. L., and Wallace, G.: Etiology

of aseptic necrosis of the head of the femur after transcervical fracture, J. Bone & Joint Surg. 24:831, 1942.
7. Dickson, J. A.: The "unsolved" fracture; a protest against defeatism, J. Bone & Joint Surg. 35:805, 1953.
8. Eaton, G. O.: Internal fixation in displaced fractures of the femoral neck, J. Bone & Joint Surg. 38A:23, 1956.
9. Eggers, G. W., Shindler, T. O., and Pomerat, C. M.: The influence of contact compression factor on osteogenesis in surgical fracture, J. Bone & Joint Surg. 31A: 693, 1949.
10. Inman, V. T.: *Functional aspects of the* abductor muscles of the hip, J. Bone & Joint Surg. 29:607, 1947.
11. King, Thomas: The closed operation for intracapsular fracture of the neck of the femur, final results in recent and old cases, Brit. J. Surg. 26:721, 1939.
12. ———: Compression of the bone ends as an aid to union in fractures, J. Bone & Joint Surg. 39:1238, 1957.
13. McElvenny, R. T.: The immediate treatment of intracapsular hip fracture *in* Clinical Orthopaedics, No. 10, p. 289, Philadelphia, Lippincott, 1957.
14. Martz, C. D.: Stress tolerance of bone and metal, J. Bone & Joint Surg. 38A:527, 1956.
15. Nyström, Gunnar: Osteosynthesis of medial fractures of the neck of the femur with aid of three nails (multiple nailing), Acta chir. scandinav. 107:89, 1954.
16. Phemister, D. B.: Changes in bone and joints resulting from interruption of circulation. General considerations and changes resulting from injuries, Arch. Surg. 41:436, 1940.
17. ———: Fracture of neck of femur, dislocation of hip and obscure vascular disturbances producing aseptic necrosis of head of femur, Surg, Gynec. & Obst. 59: 415, 1934.
18. Santos, J. V.: Changes in the head of the femur after complete intracapsular fracture of the neck, their bearing on nonunion and treatment, Arch. Surg. 21:470, 1930.
19. Sherman, M. S., and Phemister, D. B.: The pathology of ununited fracture of neck of femur, J. Bone & Joint Surg. 29:19-40, 1947.
20. Speed, J. S.: Central fractures of the neck of the femur, J.A.M.A. 104:2059-2063, 1935.
21. Watson-Jones, Sir Reginald: Fractures and Joint Injuries, vols. 1 & 2, Baltimore, Williams & Wilkins, 1952, 1955.

Fixation Absolute con Compression de Contacto in Fracturas Coxal (Un Nove Dispositivo de Fixation)

Summario in Interlingua

Pro meliorar additionalmente le resultatos del tractamento chirurgic de fracturas coxal, le autor propone le effectuation de fixation absolute ■ de compression de contacto per medio de un nove typo de placa obtenibile sub le nomine de 'placa Deyerle' ab le Compania Price-Filler in Roanoke, Virginia. Le placa servi como guida in le accurate placiamento de multiple broches de fixation. Illo ha un foramine central de un diametro de un medie pollice. Isto guida le accurate placiamento del graffo de osso cancellose, parallel al broches ■ satis profundemente a in le capite femoral. Le graffo pote esser effectuate como manovra primari o secundari. Le foramine central pote etiam esser usate pro le insertion de un glissante clavo Smith-Petersen.

Le broches es filettate solmente in le portion que se trova in prisa con le capite femoral e pote glissar liberemente in le cortice distal e etiam in le placa. Isto rende possibile que on pulsa le broches de fixation completemente usque al cortice articular. Si un accurtamento occurre al sito del fractura, le broches pote glissar in direction distal in le placa sin resultante disturbation del stato de fixation del capite a un preseligite angulo, que es usualmente cento quaranta grados. Le placa es fixate al dia-

physe del femore, sed le broches de fixation e le clavo Smith-Petersen (si usate) pote glissar de maniera a permitter un continue compression de contacto al superficies del fractura. Cinque broches de fixation de un calibre de un octave pollice, inserite in le capite femoral, mantene le reduction valge mesmo in caso de recomenciamento immediate de ambulation.

In omne isto, le principios a observar es (1) immobilisation absolute e (2) compression de contacto. Le effecto del application de iste principios es le stimulation de un union precoce e prompte, proque al sito del fractura amne motion cisorial o glissante es prevenite. Isto assecura un maximo de protection pro le disveloppamento de nove vasos de sanguine que pote establir un connexion, a transverso le fractura, con le capite del femore. Le absentia de fixation absolute destrue le nove vasos de sanguine ante que lor disveloppamento es complete e obstrue le formation de vasos de sanguine in le futuro in consequentia del formation de un strato de histo cicatricular. Le resultato es un retardo del union e un augmento del risco de non-union e possibilemente le prevention del disveloppamento de un sufficiente numero de connexiones vascular pro mantener le viabilitate del capite femoral. Necrose aseptic es insufficientia vascular in le capite. Proque le placa pote etiam esser usate como guida, un graffo pote esser inserite si tosto que le prime signo adverse deveni manifeste. Un tal graffo non disturba le union que ha jam comenciate, e illo causa nulle perdita de fixation. Le complete effectuation del graffage, in que cancellose osso iliac es usate, require minus que quaranta-cinque minutas.

27

A Clinical Study of 46 Males With Low-Back Disorders Treated With Methocarbamol

A Preliminary Report from Veterans Administration Hospital, Grand Island, Nebraska

ANDRES GRISOLIA, M.D.,* AND J. E. M. THOMSON, M.D.†

We present here an analysis of data collected during a study of 46 nonselected consecutive patients admitted to the Veterans Administration Hospital, Grand Island, Neb., since October 15, 1957, with the chief complaint of low-back pain. On that date we started using 3-(o-methoxyphenoxy)-2-hydroxypropyl carbamate (Robaxin) for those patients in whom conservative treatment was indicated. We will refer to these patients as Group A.

Another 46 patients with the same diagnoses as those of Group A, admitted to the hospital immediately before October 15, 1957, were chosen in strict chronologic order. We will refer to these patients as Group B. Patients in Group B also were treated conservatively, but they did not receive methocarbamol and are used to compare the clinical effect of the drug.

The diagnoses of the patients in Group A are listed in Table 1. The patients in Group B have, of course, the same diagnoses.

Patients with diagnoses of simple lumbosacral sprain were classified for convenience as Acute if they had had no previous history of low-back pain, and Chronic if they had had two or more episodes of low-back pain.

All patients in both groups were males. The youngest patient in Group A was 28 years old and the oldest 67, the average age

* Chief, Orthopedic Section, Veterans Administration Consolidated Center, Wadsworth Division, Wadsworth, Kan.

† Consultant in Orthopedic Surgery at the Veterans Administration Hospital, Grand Island, Neb.

TABLE 1

DIAGNOSIS	NUMBER OF CASES	AVERAGE AGE (Years) Group A	Group B
Chronic lumbosacral sprain	16 — 34.78%	38	43
Acute lumbosacral sprain	11 — 23.91%	36	47
Osteoarthritis	11 — 23.91%	60	56
Herniated intervertebral disk	8 — 17.39%	38	42
Total	46 100%	41	44

being 41. The youngest patient in Group B was 28 years old and the oldest 69, the average age being 44 (Table 1).

The following symptoms were present in both groups of patients: Low-back pain, radiated pain and stiffness.

1. **Low-Back Pain.** All patients in both groups had the primary symptom of low-back pain (Table 2). Three patients in Group A and 2 patients in Group B had moderate pain and the rest had severe pain.

TABLE 2

Low-Back Pain	Moderate	Severe	Total
Group A	3	43	46
Group B	2	44	46

2. **Radiated Pain.** In Group A, 35 patients, or 76.09 per cent, had radiated pain to one or both legs (Table 3). In Group B, 34 patients, or 73.91 per cent, had radiated pain of similar distribution.

3. **Stiffness.** All patients in both groups had some degree of stiffness (Table 4).

The following signs were evaluated in both groups of patients: Tenderness, muscle spasm, limitation of motion, and straight-leg-raising.

1. **Tenderness.** Tenderness in the lum-

TABLE 3

Radiated Pain	Right Leg Gr. A	Right Leg Gr. B	Left Leg Gr. A	Left Leg Gr. B	Both Legs Gr. A	Both Legs Gr. B	Total Gr. A	Total Gr. B
Chronic L.S.	5	2	6	3	3	6	14	11
Acute L.S.	4	4	2	1	0	1	6	6
Osteoarthritis	1	2	2	5	4	2	7	9
Herniated disk	4	5	4	3			8	8
Total.							35	34

TABLE 4

Stiffness	Severe Gr. A	Severe Gr. B	Moderate Gr. A	Moderate Gr. B	Total Gr. A	Total Gr. B
Chronic L.S.	10	8	6	8	16	16
Acute L.S.	7	4	4	7	11	11
Osteoarthritis	6	8	5	3	11	11
Herniated disk	7	6	1	2	8	8
Total........................	30	26	16	20	46	46

TABLE 5

Tenderness	Severe Gr. A	Severe Gr. B	Moderate Gr. A	Moderate Gr. B	Slight Gr. A	Slight Gr. B	Total Gr. A	Total Gr. B
Chronic L.S.	4	5	7	8	5	3	16	16
Acute L.S.	9	10	2	1			11	11
Osteoarthritis	7	4	4	7			11	11
Herniated disk	7	5	1	3			[illegible]	8
Total	27	24	14	19	5	3	46	46

bar region—generally in the mid-line—was present in all patients (Table 5).

2. Muscle Spasm. All patients in both groups had some degree of paravertebral muscle spasm (Table 6), which was classified as marked, moderate or slight.

3. Motion. The range of motion of the vertebral spine in the anteroposterior and lateral plane was tested and classified as normal or slightly, moderately or markedly limited. The frequency of limitation is presented in Table 7.

4. Straight-Leg-Raising. This sign also was tested in all patients, and the results indicated as normal or slightly, moderately or markedly limited are shown in Table 8.

The neurologic signs, when present, or the roentgenographic findings are not presented here.

We used methocarbamol routinely in association with other accepted forms of treatment; namely, bed rest, traction, physical therapy and braces, as indicated. However, no sedatives or analgesics were used on any patient in Group A, whereas patients in Group B were given mild analgesic medication in addition to the above-mentioned treatment.

TABLE 6

Muscle Spasm	Marked Gr. A	Marked Gr. B	Moderate Gr. A	Moderate Gr. B	Slight Gr. A	Slight Gr. B	Total Gr. A	Total Gr. B
Chronic L.S.	3	3	6	4	7	9	16	16
Acute L.S	8	6	3	2		3	11	11
Osteoarthritis	4	5	4	1	3	5	11	11
Herniated disk	7	6	1	2			8	8
Total	22	20	14	9	10	17	46	46

TABLE 7

Limitation of Motion	Marked Gr A	Marked Gr. B	Moderate Gr A	Moderate Gr. B	Slight Gr. A	Slight Gr. B	None Gr. A	None Gr. B	Total Gr. A	Total Gr. B
Chronic L S.			2	1	6	8	8	7	16	16
Acute L S.	3	2	6	4	2	5			11	11
Osteoarthritis	1	2	3	1	5	6	2	2	11	11
Herniated disk	2	3	4	4	2	1			8	8
Total	6	7	15	10	15	20	10	9	46	46

TABLE 8

Straight-Leg-Raising	Markedly Limited Gr. A	Markedly Limited Gr. B	Moderately Limited Gr. A	Moderately Limited Gr. B	Slightly Limited Gr. A	Slightly Limited Gr. B	Not Limited Gr. A	Not Limited Gr. B	Total Gr. A	Total Gr. B
Chronic L.S.	3	3	3	5	7	4	3	4	16	16
Acute L.S	2	1	2	2	4	4	3	4	11	11
Osteoarthritis	1	2	2	1	2	3	6	5	11	11
Herniated disk	6	5	1			1	1	2	8	8
Total	12	11	8	8	13	12	13	15	46	46

TABLE 9

	Daily Dose of Methocarbamol			Duration of Treatment with Methocarbamol (in Days)		
	4 Gm.	6 Gm.	8 Gm.	Minimum	Maximum	Average
Chronic L.S. ..	14	2		3	45	16.06
Acute L.S.	7	1	3	3	61	21.45
Osteoarthritis ..	5	5	1	7	58	26.90
Herniated disk .	3	3	2	14	51	30
Total.	29 (63%)	11 (24%)	6 (13%)		Total average	23.85

TABLE 10

Results	Marked Gr. A	Marked Gr. B	Moderate Gr. A	Moderate Gr. B	Slight Gr. A	Slight Gr. B	Negative Gr. A	Negative Gr. B
Chronic L.S.	11	8	2	2		2	3	4
Acute L.S.	7	5	1			1	3	5
Osteoarthritis	4	1	2	3	2	4	3	3
Herniated disk	5	4	1		1	1	1	3
Total...... .	27	18	6	5	3	8	10	15

Total Results	Group A	Group B
Beneficial	36 (78.46%)	31 (67.39%)
Negative	10 (21.54%)	15 (32.61%)

The initial daily dose of methocarbamol was 4 Gm., divided into 4 doses. However, in 24 per cent of the patients, the dose was increased to 6 Gm., and in 13 per cent of the patients it was increased to 8 Gm. daily (Table 9).

The length of treatment with methocarbamol was from a minimum of 3 days to a maximum of 61 days, with an average of 23.85 days (Table 9).

RESULTS

The results of treatment with methocarbamol of the group of patients studied here have been extremely variable. In several patients the effect of the drug was dramatic; in others, it gave no relief. To illustrate its potency, a case report is given:

Since 1946 this 45-year-old white, married, male farmer had had recurrent attacks of low-back pain that radiated to the left leg. Thirty days prior to admission he developed progressively increasing pain and was unable to work. The pain became so severe that hospitalization was necessary. Examination showed (1) moderate tenderness on the lumbar region at the level of L-5; (2) slight paravertebral muscle spasm; (3) straight-leg-raising of 40° on the left and 80° on the right, with positive Lasègue sign on the left; (4) normal neurologic examination. His diagnosis was chronic lumbosacral sprain. The patient was placed on bed rest and 1 Gm. of methocarbamol q.i.d. In 48 hours he was symptom free, and his examination did not show

TABLE 11

NUMBER OF HOSPITAL DAYS	MINIMUM Gr. A	MINIMUM Gr. B	MAXIMUM Gr. A	MAXIMUM Gr. B	AVERAGE Gr. A	AVERAGE Gr. B
Chronic L.S.	3	5	23	82	14.7	30
Acute L.S.	7	8	38	65	21.63	26.63
Osteoarthritis	4	4	53	41	19.63	22.36
Herniated disk	15	16	40	49	25.62	30.75
Total average					20.39	24.93

TABLE 12

SIDE EFFECTS	NAUSEA	SKIN RASH	TOTAL
Chronic L.S.	1		1
Acute L.S.	1	1	2
Osteoarthritis			
Herniated disk	1		1
Total	3	1	4 (8.6%)

any of the signs listed above. He was discharged on the third day, and to date there has been no recurrence of symptoms.

On the other hand, we found patients in whom no favorable result was obtained from the use of methocarbamol.

To evaluate the results, we graded the improvement of patients at the end of treatment as follows:

1. Marked. When the patient did not have any of the symptoms or signs present at admission.

2. Moderate. When the patient had one remaining symptom but no signs.

3. Slight. When the patient had one symptom and/or a clinical finding of those found on admission.

4. Negative. When the patient had more than one remaining symptom and/or clinical sign found previously.

This evaluation is presented in Table 10. All patients were evaluated initially and finally by either one of us, and in most instances by both of us.

In Group A, 78.46 per cent of the patients improved under conservative treatment plus methocarbamol. In Group B, 67.39 per cent of patients improved with conservative treatment alone. This represents 11.07 per cent more favorable results in patients of Group A.

Finally, we evaluated the length of hospitalization in both groups of patients (Table 11). Patients in Group A averaged 4.54 (or 18.21%) less days in the hospital than the patients in Group B.

We found side-effects with the use of this drug in 8.6 per cent of our cases (Table 12).

At present, we are engaged in a double blind study of this drug.

We are aware of the contributions and the studies that have appeared in the literature and of the research being carried out by pharmaceutical houses. We are aware, too, that this preliminary report is inconclusive. But our purpose is to stimulate investigation of the value of this product and similar ones.

SUMMARY AND CONCLUSIONS

1. Forty-six patients with the primary symptom of low-back pain who were treated conservatively were given methocarbamol and compared with 46 patients with similar conditions who were also treated conservatively but did not receive this drug.

28

Brucellar Bursitis With Negative Agglutination and Skin Tests

A Case Report

ROBERT E. VAN DEMARK, M.D., F.A.C.S., AND
CHARLES B. MITCHELL, M.D., F.A.C.P.*

A significant number of the population in rural areas of the Midwest show agglutination for Brucella in titers above 1:64 on serologic examination. In many of these, the brucallergen test is positive, yet the patients have no definite clinical findings.

In the case under discussion these tests were negative in the presence of a primary clinical impression of brucellar bursitis. The difficulty of diagnosis is well illustrated in this case.

In a report, in 1954, from the Mayo Clinic by Johnson and Weed,[2] 4 cases of brucellar bursitis were reported. These authors were able to find only 1 report of a case of brucellar bursitis[3] and stated that the condition seemed to be rare.

A white male, farmer by occupation, age 47, was seen on November 1, 1956, because of recurrent swelling of the left knee. The onset of the swelling had dated to 1950; it disappeared spontaneously only to recur at increasingly frequent intervals until continuous swelling was present. In January, 1955, the mass had been excised, and the pathologic diagnosis at the University of Minnesota was bursitis of the left knee.

Physical examination showed swelling of the left knee on the lateral and the anterior aspects of the left patella, as well as the old scar of previous operation. There was no drainage at this time, although there had been a history of previous drainage, and the site of the previous operation was present laterally. The roentgenograms of the knee (Fig. 1) showed no joint abnormality; there was a congenital bipartite patella, which was not considered to be of any significance. The sedimentation rate was elevated to 40 mm. per hour (Westergren). This patient gave a history of having had a heifer with a positive test for Bang's disease in 1950; subsequent tests were not considered to be positive, and the first test had been regarded as a false positive. Because of this history, agglutination tests were run for brucellosis, as well as a skin test with brucallergen, both of which were negative.

The patient was admitted to Sioux Valley Hospital on November 7, 1956, at which time a large bursa was excised from the left knee in the prepatellar area; the bursa extended exceptionally far laterally. The postoperative course was satisfactory, and the patient was dismissed from the hospital on November 16, 1956. Cultures from the bursa for the Brucella organism were reported to be negative by the laboratory. The pathologic diagnosis was a nonspecific bursitis of the left knee (Figs. 2 & 3). The wound was slow in healing, but it did heal finally, and the patient appeared to have an excellent result when he was seen on July 2, 1957.

On November 5, 1957, the patient returned with recurrence of the swelling, this time located on the medial aspect of the left knee. The site of the previous surgery was well healed. He was readmitted to the hospital on November 14, 1957, and on the following day underwent excision of a superficial bursalike structure. At a

* Sioux Falls, S. Dak.

preoperative conference between his surgeon and the pathologist it was decided to take a warm culture from the biopsy material in the operating room. This was done. The material revealed an organism identified as *Brucella abortus*, as confirmed in the laboratory of Dr. Wesley Spink at the University of Minnesota. Spink, after examination of the serum from the patient, stated that there were blocking antibodies, which explained the negative agglutination test in the patient. The agglutination test was reperformed, using the antiglobulin serum of the Coombs test to detect the presence of blocking antibodies. The agglutination then was positive to a titer of 1:640.

The patient was last seen on May 28, 1958. The knee showed no evidence of recurrence of the bursitis; extension was 180° and flexion 45°. The patient's sedimentation rate was 5 mm. per hour (Westergren method). The patient was requested to return for further examination in 4 months, or sooner if he was having any trouble

COMMENT

Prior to the recognition of the Brucella agglutinin blocking factor,[1,4] it was stated[5] that in chronic brucellosis "the anergic type *typically shows a negative skin test for the* organism, and antibodies in the blood cannot be demonstrated." These negative findings probably have contributed to the extreme rarity[2,3] of the diagnosis of brucellar bursitis. When the clinical diagnosis of brucellar bursitis is probable and the routine agglutination tests are negative, the presence or the absence of blocking antibodies should be determined.

FIG. 2. Synovial cavity with surrounding fibroplastic response and severe chronic inflammatory infiltrate (×90). (Dr. Amos Michael, U. S. D. Med. School)

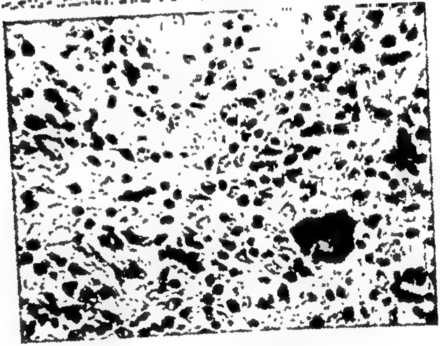


FIG. 3. High-power view near synovial cavity showing characteristic round-cell infiltrate and a giant cell resembling the Langhan type. Giant cells are uncommon (×466). (Dr. Amos Michael, U. S. D. Med. School)

In the cases reported previously[2,3] no data are presented on the presence or the absence of blocking antibodies. After removal of the blocking antibodies a negative agglutination test may be markedly positive. Therefore, a negative agglutination test cannot be regarded as final until the presence of blocking antibodies has been ruled out.

Isolation of the organism is necessary for the diagnosis; it is cultured only with difficulty and under optimum conditions.

As of this time, the results of intensive Terramycin therapy in this case have remained good.

SUMMARY

A proven case of brucellar bursitis is reported; it differs from the small number of cases reported previously[2,3] in that blocking antibodies were demonstrated. After removal of the blocking antibodies the agglutination test changed from negative to a markedly positive test (1:640).

The patient was a farmer who had a possible contact with a case of bovine brucellosis, he later developed a chronic recurrent bursitis. Brucellar bursitis was suspected, but the skin test, the agglutination and the culture on excision of the bursa

were all negative. After recurrence of the bursitis, a positive growth of *Brucella abortus* was obtained on warm culture of the immediately excised surgical specimen. Blocking antibodies subsequently were demonstrated in the sera, and after their removal the agglutination test was positive (1:640). To date, the patient's clinical response to intensive Terramycin therapy has been good.

A negative agglutination test for undulant fever cannot be regarded as final until the presence of blocking antibodies has been ruled out. The definite diagnosis of brucellar bursitis is dependent on the demonstration of the organisms, which may be cultured only with difficulty.

REFERENCES

1. Cox, C. D., and Kutner, L. J.: Brucella agglutinin-blocking phenomenon in bovine sera, Science 111:545-546, 1950.
2. Johnson, E. W., Jr., and Weed, L. A.: Brucellar bursitis, J. Bone & Joint Surg. 36A:133-139, 1954.
3. Kennedy, J. C.: Notes on chronic synovitis or bursitis, due to the organism of Mediterranean fever, J. Roy. Army M. Corps 2:178-180, 1904.
4. Schuhavdt, V. T., Woodfin, H. W., and Knolle, K. C.: A heat-labile Brucella-agglutinin-blocking factor in human sera, J. Bact. 61:299-303, 1951.
5. Smith, D. T., and Martin, D. S.: Zinsser's Textbook of Bacteriology, ed. 9, New York, Appleton, 1948.

Bursitis Brucellari

Summario in Interlingua

Es reportate un caso demonstrate de bursitis brucellari. Illo differe del micre numero de previemente reportate casos[2,3] in tanto que anticorpore blocante esseva demonstrate. Post le elimination de iste factor, le test de agglutination cambiava ab negative a marcatemente positive (1:640).

Le patiente esseva un fermero e possibilemente habeva habite contacto con un caso de brucellosis bovin. Subsequentemente ille disveloppava recurrente bursitis chronic. Bursitis brucellari esseva suspicite, sed le test cutanee, le test de agglutination, e le cultura post excision del bursa esseva omnes negative. Post recurrentia del bursitis, un cultura positive de *Brucella abortus* esseva obtenite per via calide ab le frescamente excisionate specimen chirurgic. Anticorpore blocante esseva demonstrate subsequentemente in le seros. Il esseva hic que le elimination del anticorpore blocante resultava in un positive test de agglutination (1:640). Le responsa clinic del patiente a un therapia intense con terramycina esseva bon. Nulle recurrentia ha apparite usque al tempore del presente reporto.

Negativitate del test de agglutination pro febre undulante non pote esser considerate como final usque le presentia de anticorpore blocante ha essite disprovate. Le diagnose definite de bursitis brucellari depende del demonstration del organismo, e isto es difficile a culturar.

29

Acute Traumatic Extrusion of the Acromioclavicular Disk*

A Case Report

ELIHU FRIEDMANN, M.D.†

Acute dislocation of an acromioclavicular disk has been described associated with a complete disruption of the acromioclavicular joint and tears of the conoid and the trapezoid ligaments.[2,3] However, to the author's knowledge, an extrusion of the disk from the joint without apparent disruption of any of the other clavicular relationships has not hitherto been reported.

DePalma's anatomic studies[1] on the acromioclavicular joint in people of varied ages have shown that while the disk is uniformly present in those below the age of 20, degeneration occurs in this joint at an early age, and destruction of the disk often ensues. Thus, many people who reach adult life no longer have evidence of a disk in this joint.

The acromioclavicular articulation is an arthrodial joint between the acromial end of the clavicle and the medial margin of the acromial portion of the scapula. The articular capsule completely surrounds the articular margins and is strengthened above and below by the superior and the inferior acromioclavicular ligaments. When it is present, the acromioclavicular disk is attached to the superior part of the joint and, in the adult, divides the joint cavity to a varying degree into two cavities. Only rarely does it divide the joint completely into two cavities, and occasionally it is perforated in the center.

On September 1, 1954, a 53-year-old post office employee was seen because of pain in the region of the left shoulder of 1 day's duration. The day before, while lifting a sack of mail, he was seized suddenly with pain in the region of the left acromioclavicular joint. Marked swelling was noticed in this area, but no medical care was sought. The following day on returning to work he attempted to lift again but was unable to do so because of pain referred to this area.

On physical examination there was a visible mass measuring 1.5 cm. in its greatest diameter over the region of the left acromioclavicular joint (Fig. 1). The clavicle itself did not seem to be elevated or displaced, but there was exquisite pain over the region of the mass. Ranges of motion of the shoulder were essentially normal Maximal pain was referred to the mass when, on test, the patient attempted to lift a heavy object. The mass, palpably firm and of cartilaginous consistency, was not attached to subcutaneous tissues and apparently was fixed to deeper structures. It was slightly movable and very tender. The shoulder joint was intact on detailed physical examination. The upper extremity otherwise was normal.

Standing roentgenographic examination of both shoulders with 10 pounds in each hand showed normal relationships in both the acromioclavicular joints. There was no narrowing or other change of the affected left acromioclavicular joint (Fig 2) as compared with the right.

* The author is indebted to Dr. Joseph E. Milgram for his helpful guidance and to Dr. Golden Selin for the description of the microscopic specimen.

† Scranton, Pa.

were all negative. After recurrence of the bursitis, a positive growth of *Brucella abortus* was obtained on warm culture of the immediately excised surgical specimen. Blocking antibodies subsequently were demonstrated in the sera, and after their removal the agglutination test was positive (1:640). To date, the patient's clinical response to intensive Terramycin therapy has been good.

A negative agglutination test for undulant fever cannot be regarded as final until the presence of blocking antibodies has been ruled out. The definite diagnosis of brucellar bursitis is dependent on the demonstration of the organisms, which may be cultured only with difficulty.

REFERENCES

1. Cox, C. D., and Kutner, L. J.: Brucella agglutinin-blocking phenomenon in bovine sera, Science 111:545-546, 1950.
2. Johnson, E. W., Jr., and Weed, L. A.: Brucellar bursitis, J. Bone & Joint Surg 36A:133-139, 1954.
3. Kennedy, J. C.: Notes on chronic synovitis or bursitis, due to the organism of Mediterranean fever, J. Roy. Army M. Corps 2:178-180, 1904.
4. Schuhavdt, V. T., Woodfin, H. W., and Knolle, K. C.: A heat-labile Brucella-agglutinin-blocking factor in human sera, J. Bact. 61:299-303, 1951.
5. Smith, D. T., and Martin, D. S.: Zinsser's Textbook of Bacteriology, ed. 9, New York, Appleton, 1948.

Bursitis Brucellari

Summario in Interlingua

Es reportate un caso demonstrate de bursitis brucellari. Illo differe del micre numero de previemente reportate casos[2,3] in tanto que anticorpore blocante esseva demonstrate. Post le elimination de iste factor, le test de agglutination cambiava ab negative a marcatemente positive (1:640).

Le patiente esseva un fermero e possibilemente habeva habite contacto con un caso de brucellosis bovin. Subsequentemente ille disveloppava recurrente bursitis chronic. Bursitis brucellari esseva suspicite, sed le test cutanee, le test de agglutination, e le cultura post excision del bursa esseva omnes negative. Post recurrentia del bursitis, un cultura positive de *Brucella abortus* esseva obtenite per via calide ab le frescamente excisionate specimen chirurgic. Anticorpore blocante esseva demonstrate subsequentemente in le seros. Il esseva hic que le elimination del anticorpore blocante resultava in un positive test de agglutination (1:640). Le responsa clinic del patiente a un therapia intense con terramycina esseva bon. Nulle recurrentia ha apparite usque al tempore del presente reporto.

Negativitate del test de agglutination pro febre undulante non pote esser considerate como final usque le presentia de anticorpore blocante ha essite disprovate. Le diagnose definite de bursitis brucellari depende del demonstration del organismo, e isto es difficile a culturar.

29

Acute Traumatic Extrusion of the Acromioclavicular Disk*

A Case Report

ELIHU FRIEDMANN, M.D.†

Acute dislocation of an acromioclavicular disk has been described associated with a complete disruption of the acromioclavicular joint and tears of the conoid and the trapezoid ligaments.[2,3] However, to the author's knowledge, an extrusion of the disk from the joint without apparent disruption of any of the other clavicular relationships has not hitherto been reported.

DePalma's anatomic studies[1] on the acromioclavicular joint in people of varied ages have shown that while the disk is uniformly present in those below the age of 20, degeneration occurs in this joint at an early age, and destruction of the disk often ensues. Thus, many people who reach adult life no longer have evidence of a disk in this joint.

The acromioclavicular articulation is an arthrodial joint between the acromial end of the clavicle and the medial margin of the acromial portion of the scapula. The articular capsule completely surrounds the articular margins and is strengthened above and below by the superior and the inferior acromioclavicular ligaments. When it is present, the acromioclavicular disk is attached to the superior part of the joint and, in the adult, divides the joint cavity to a varying degree into two cavities. Only rarely does it divide the joint completely into two cavities, and occasionally it is perforated in the center.

On September 1, 1954, a 53-year-old post office employee was seen because of pain in the region of the left shoulder of 1 day's duration. The day before, while lifting a sack of mail, he was seized suddenly with pain in the region of the left acromioclavicular joint. Marked swelling was noticed in this area, but no medical care was sought. The following day on returning to work he attempted to lift again but was unable to do so because of pain referred to this area.

On physical examination there was a visible mass measuring 1.5 cm. in its greatest diameter over the region of the left acromioclavicular joint (Fig. 1). The clavicle itself did not seem to be elevated or displaced, but there was exquisite pain over the region of the mass. Ranges of motion of the shoulder were essentially normal. Maximal pain was referred to the mass when, on test, the patient attempted to lift a heavy object. The mass, palpably firm and of cartilaginous consistency, was not attached to subcutaneous tissues and apparently was fixed to deeper structures. It was slightly movable and very tender. The shoulder joint was intact on detailed physical examination. The upper extremity otherwise was normal.

Standing roentgenographic examination of both shoulders with 10 pounds in each hand showed normal relationships in both the acromioclavicular joints. There was no narrowing or other change of the affected left acromioclavicular joint (Fig. 2) as compared with the right.

* The author is indebted to Dr. Joseph E. Milgram for his helpful guidance and to Dr. Golden Selin for the description of the microscopic specimen.

† Scranton, Pa.

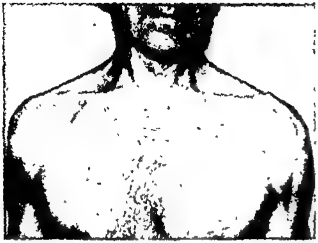


Fig. 1. Preoperative subcutaneous mass visible on left corresponding to extruded disk. Right side was normal.

Fig. 2. Preoperative roentgenogram of the left acromioclavicular joint with a 10-pound weight in the left hand demonstrating the normal joint relationships.

Fig. 3. Gross specimen—extruded acromioclavicular disk.

Diagnosis was made of an acute extrusion of the left acromioclavicular disk, and surgery was advised, the rarity of this lesion not being realized.

On September 2, 1954, the patient was subjected to surgery, and the acromioclavicular disk was found to have extruded completely out of the joint superiorly and lay subcutaneously. The disk was attached to the joint by the medial portion of the superior acromioclavicular ligament and rotated medially, the lateral portion of the ligament being completely torn. The joint itself showed no other changes in its normal relationships. However, a defect was visible in the superior aspect of the joint capsule, with frayed edges, and was obviously a rent through which the disk had left the joint. A space was left between the clavicle and the acromion that corresponded in size and shape to the extruded disk and measured 1.3 x 1 x 0.8 cm. The disk was grossly cartilaginous, smooth on one side and irregular on the others (*Fig. 3*).

On pathologic examination the firm portion of the disk measured 1.3 x 1 x 0.8 cm. It was firm and somewhat cartilaginous in consistency, having a smooth articular surface on one side and being irregular on all other sides. It was of

a grayish-white color. The microscopic section (Fig. 4) shows a diarthrodial joint. The fibrocartilage of the joint space shows a moderate amount of degeneration, characterized by a breaking up into stringy fragments and slight liquefaction. These changes occur at the distal end of the cartilage attached to the bone. There is no evidence of tearing at the bone-cartilage junction. There is also no evidence of tearing of the periosteal or the fascial attachments over the surface of the bone. Tumor is not evident. Inflammation is not evident.

The patient's postoperative course was uneventful. He returned to work in 5 weeks with minimal pain and disability. He had an excellent range of motion of the shoulder with no discernible limitation of motion. He was last seen on October 14, 1954, with satisfactory motion without pain (Fig 5).

The exact nature of this disk extrusion is not clear. However, it may be assumed that considerable degeneration of the acromioclavicular joint structures had occurred prior to the traumatic episode. The force on this joint may then have been sufficient to tear the ligament along with enough compression of the joint surfaces to extrude the disk, much as the soft substance of a grape can be squeezed from the skin.

It is difficult to account for the poorly formed bone and articular cartilage present in the microscopic section of the extruded mass. However, this osseous tissue is noted to be insufficiently developed to appear in the preoperative roentgenogram. Therefore, it must be assumed that this osseous and cartilaginous tissue is a portion of the disk substance, especially since no evidence of

Fig. 4. Microscopic section of disk ×60 demonstrating degenerated disk fibrocartilage, articular cartilage and osseous tissue.

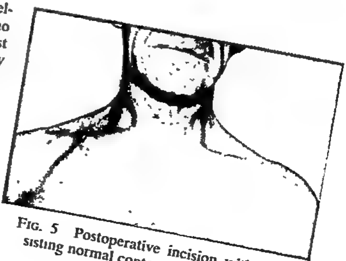


Fig. 5 Postoperative incision with persisting normal contour of the shoulder.

avulsion or fracture of the surrounding bony structures was present at operation.

SUMMARY

Acute extrusion of an acromioclavicular disk without dislocation or displacement of other acromio clavicular joint relationships has been presented. The lesion was incurred by lifting a mail sack. Surgical removal has been followed by clinical recovery in the relatively short period followed to date.

REFERENCES

1. DePalma, A. F.: Personal communication.
2. Horn, J. S : Traumatic anatomy and treatment of acute acromio-clavicular dislocation, J. Bone & Joint Surg. 36B:194-200, 1954.
3. Kennedy, J. C., and Cameron, H.: Complete dislocation of the acromio-clavicular joint, J. Bone & Joint Surg 36B:202-208, 1954.

30

Ewing's Sarcoma of the Humerus

A Case Report*

LAURO BARROS DE ABREU, M.D.† AND GODOFREDO ELEJALDE, M.D.‡

Ewing's sarcoma is accepted by nearly all who have studied this subject as a neoplastic entity with characteristic findings. Usually, it occurs in the first two decades of life. Because of its tendency to spread by multiple foci into the skeleton and the lungs, it offers a poor prognosis regardless of treatment.

Statistical data based on a large series of cases show that long survival is rare indeed. Jaffe and Lichtenstein[4] reported 17 cases; all died. Coley and others,[2] in a series of 73 patients, reported 3 with a survival of 5 and more years. Lichtenstein[3] reported a patient with Ewing's sarcoma of the fibula who survived 20 years following amputation. McCormack, Dockerty and Ghormley,[5] in a review of 63 cases at the Mayo Clinic, reported that 8 survived 5 years. Pais and Zanasi,[6] in 40 cases, reported 1 who survived more than 5 years.

The main point of interest in our case is that the patient is still alive more than 7 years after treatment consisting of radiotherapy followed by radical surgery.

CASE REPORT

A 7-year-old white girl was brought to the hospital for consultation on December 4, 1950, 7 months after the onset of symptoms. Her right shoulder was painful and swollen. Previously she had been examined elsewhere and immobilized in a plaster spica. After 40 days the plaster was discarded, but the symptoms became more severe.

The tumor mass extended from the middle of the arm to the shoulder. It was very painful, and the child was unable to move the shoulder. Passive motion was very difficult. Roentgenograms showed bone destruction.

Biopsy, with Godoy Moreira's trephine,[1]

FIG 1. Extensive bone destruction (February 7, 1951).

* From the University Hospital "Clínica Ortopédica e Traumatológica," Service of Prof Godoy Moreira, São Paulo, Brazil.

† Assistant.

‡ Pathologist.

was done on December 14, 1950, and Ewing's tumor was diagnosed.

Laboratory Examination. Alkaline phosphatase was 12.5 K.A./100 ml.; pH of alkaline substratum of disodium phenylphosphate was 9.3; calcium was 10.5/100 ml.

Another roentgenogram was taken (Fig. 1).

Treatment. Radiotherapy was started at once. From December 29, 1950, to March 26, 1951, 5.250 r were given in 23 sessions over 3 different fields.

On March 29, 1951, the arm and the shoulder were painless. Roentgenographic examination of the humerus showed progressive bone destruction. Amputation was proposed and refused by the parents.

On June 1, 1951, while the chest was clear, there was swelling of the whole limb without any pain. Surgical biopsy then confirmed the diagnosis, and radical surgery was decided upon (Fig. 2). There was fever for 2 days, 37° C. and 38.2° C. The parents were still against amputation.

Progress. When the limb became more and more swollen, operation was accepted.

Surgery. Intrascapulothoracic amputation was performed on July 3, 1951, by the technic described by Slocum.[7] The teres major and minor already were invaded (Fig. 3).

Pathology. The tumor of the diaphysis of the humerus had invaded the whole medullary canal with great destruction of the cortex in the central areas. It was soft and white-grayish in color, and the soft tissues were infiltrated by the tumor.

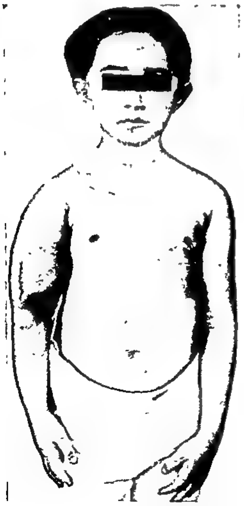


Fig. 2 The patient immediately before operation.

Fig. 3. Specimen showing aspect of the shoulder region.

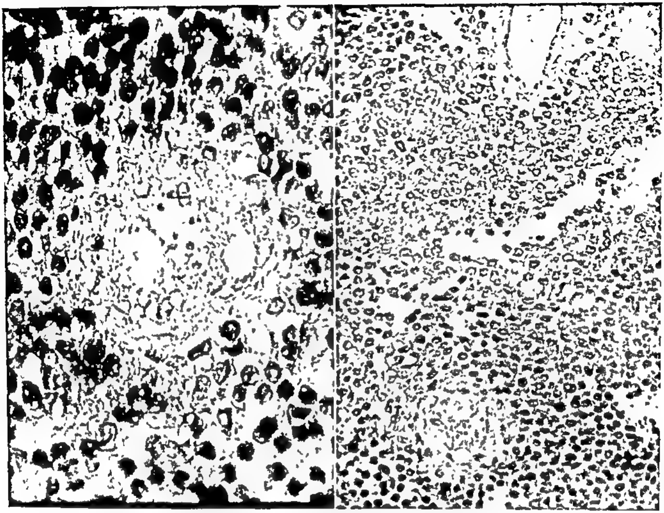


FIG. 4. Histopathologic aspects.

Specimens were taken of the tumor, and sections were stained with H.E. They showed undifferentiated neoplastic, nonosteogenic cells in syncytial disposition with nuclei of uniform size, round or ovoid, leptochromatic with scarce nucleoli and mitotic figures (Fig. 4).

The possibility of reticulum-cell lymphosarcoma was ruled out, not only because of the cellular uniformity but also because of the absence of reticulinic lymphoblastic and lymphocytic differentiation.

The hypothesis of a metastasis from a cryptic tumor in an internal organ also was ruled out because of the sufficiently long time of survival.

Results. The day after operation the temperature was 38.7° C.; otherwise, progress was uneventful.

Roentgenograms were taken 2 weeks after operation (Fig. 5) and every year thereafter. No metastases have been detected. At the moment the patient's general condition remains excellent.

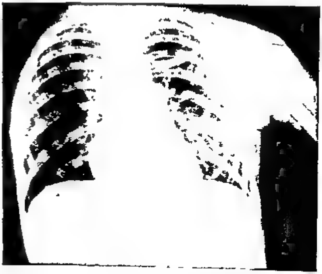


FIG 5 Roentgenogram taken on July 19, 1951, 16 days after the operation.

SUMMARY

A case is presented of a 7-year-old girl who has survived more than 7 years with Ewing's sarcoma of the humerus. Radiotherapy was given, followed by intrascapulothoracic amputation. Photographs, roentgenograms and photomicrographs taken during the treatment are shown.

Such a long survival is rare. In all such cases, early treatment by radiotherapy combined with surgery would seem to be advisable.

REFERENCES

1. Camargo, F. P.: A punção no diagnóstico das afecções osseas, Rev. cir. São Paulo 10:55-76, 1944.
2. Coley, B. L., Higinbotham, N. L., and Bowden, L.: Endothelioma of bone (Ewing's sarcoma), Ann. Surg. 128:533-560, 1948.
3. Lichtenstein, L.: Bone Tumors, p. 211 and Fig. 106, St. Louis, Mosby, 1952.
4. Lichtenstein, L., and Jaffe, H. L.: Ewing's sarcoma of bone, Am. J. Path. 23:43-77, 1947.
5. McCormack, L. J., Dockerty, M. B., and Ghormley, R. K.: Ewing's sarcoma, Cancer 5:85-99, 1952.
6. Pais, C., and Zanasi, R.: Il peritelio-sarcoma del midollo osseo (tumore de Ewing); rassegna clinica ed anatomo patologica di 40 casi, Chir. org. movimento 38:389-461, 1953.

Slocum, D. B.: An Atlas of Amputations, St. Louis, Mosby, 1949.

31

Displacement of Medial Epicondyle into the Elbow Joint

A safe, simple and painless method of reduction without surgery, manipulation, faradism or anesthesia

ERNST DEHNE, M.D.,* AND C. W. METZ, M.D.†

Blount[1] states that the majority of cases of displacement of a medial epicondyle into the elbow joint require open reduction. Patrick[2] reports that reduction could be accomplished in 40 per cent of fresh cases by manipulation. Therefore, he developed a method of reduction by faradization of the muscle attached to the displaced fragment. This method was successful in 6 consecutive cases.

The authors of this chapter can accomplish the same result without faradization by simple active contraction of the muscles around the elbow joint without anesthesia, as illustrated in the following case.

The displaced fragment of the epicondyle resulted from a dislocation of the elbow which reduced spontaneously during roentgenographic examination (Figs. 1-3). The patient then was instructed to contract the muscles around the elbow joint while the operator stabilized the forearm to prevent pain or further damage. After the muscles were seen to contract, another roentgenogram was taken and revealed acceptable position of the fragment (Figs. 4 & 5).

DISCUSSION

The efficacy of this method of reducing the medial condyle caught in the elbow joint may depend on time elapsed since injury and co-operation of the patient; nevertheless, the procedure is so atraumatic and simple that it would seem to be worth while to try it before resorting to more massive approach.

FIG. 1. Dislocation of elbow; the medial epicondyle appears displaced lateral to the capitellum.

* Colonel, Orthopedic Consultant to the 6th Army

† Lt. Colonel, Chief, Orthopedic Service, Fort Ord, Calif.

Fig. 2. Spontaneous reduction of dislocation during roentgenographic examination, but the incarceration of the medial condyle persists.

Fig. 4. Position of epicondyle immediately after reduction, accomplished by active muscle contraction without anesthesia.

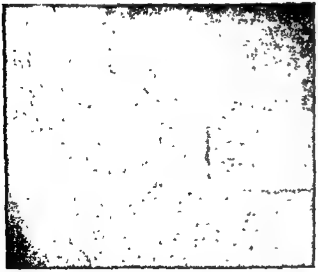


Fig 3. Spontaneous reduction of dislocation except for intra-articular incarceration of medial condyle

Fig. 5. Three months later the patient has recovered full motion of the elbow, and there is healing with full stability of the joint.

REFERENCES

1. Blount, W P : Fractures in Children, p. 55, Baltimore, Williams & Wilkins, 1955
2. Patrick, J Fracture of the medical epicondyle with displacement into the elbow joint, J. Bone & Joint Surg 28:143, 1946.

32

Excision of the Fifth Metatarsal Head

DUNCAN C. MCKEEVER, M.D., F.A.C.S.*

Various problems involving the fifth metatarsal segment of the foot have always constituted a minor annoyance, especially since man began to wear shoes. The so-called bunionette, or tailor bunion, in which an ever-enlarging exostosis on the outer side of the fifth metatarsal head incites the formation of a clavus, is common. It rarely seems to be sufficiently serious to warrant surgical attack, but a patient who is having other operative work done on the feet often wants to have such a condition remedied.

Congenital subluxation of the fifth metatarsophalangeal joint with deformity of the fifth toe is of common occurrence, and, when the joint is badly subluxated, the toe is subject to friction and pressure, depending on the degree and the direction of the deformity.

Pressure between the various components of the fourth and the fifth metatarsophalangeal joints may result in soft-corn formation.

Due to concentration of weight-bearing, a heavy painful callus may develop under the fifth metatarsal head. More than one of these conditions may be present in the same foot.

In the course of the past 15 years, the author's treatment of these conditions has developed along the following lines and finally has evolved into a single treatment for all of them.

In the beginning, bunionette was treated by removal of the exostosis. Frequently these exostoses recurred. If too much bone was removed, subluxation of the joint occurred. Often, callus on the fifth toe continued to be a source of irritation. Excision of the entire fifth metatarsal head relieved the condition, but resulted many times in the formation of a callus under or on the lateral surface of the remaining end of the fifth metatarsal.

In subluxation of the fifth metatarsophalangeal joint, plastic procedures on the joint itself rarely result in restoration of the toe to normal position, and, even if such a successful result were obtained, the toe might rub on the side of the shoe and result in an uncomfortable callus.

Soft corns can be relieved by removing the opposed bony prominences, but such relief may not be permanent, and frequently soft corns occur in association with subluxation of the fifth metatarsophalangeal joint and bunionette.

If there is a callus under the head of the fifth metatarsal, a conservative resection of the undersurface of the head may not relieve completely the pressure concentration, and a more extensive resection may result in subluxation of the joint.

Many patients object to complete removal of the fifth toe, even though it is nonfunctional and its removal is not disfiguring. Callus formation under the end of the metatarsal may occur subsequently.

Having tried all these things and having had them fail occasionally, I began to resect more and more of the fifth metatarsal in conjunction with amputation of the fifth toe, finally arriving at a beveled-off osteotomy slightly proximal to the middle of the fifth

* Houston, Tex.

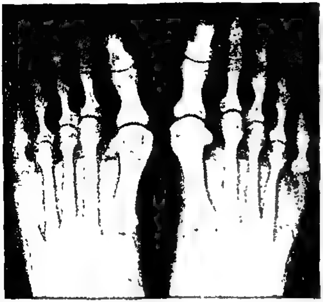


FIG. 1. Roentgenogram showing extent of resection.

metatarsal with removal of all the metatarsal distal to this (Fig. 1). This resection amounts to between one half and two thirds of the distal portion of the metatarsal. I then began to remove the metatarsal without amputation of the toe. In the last 6 years I have performed this operation over 60 times on 38 patients with uniform success. Removal of the head of the metatarsal is accepted much more readily by patients than amputation of the fifth toe. The only cases that have had any subsequent complaint whatever are the early ones, in which surgery was too conservative and the metatarsal was resected distal to the middle None of these has required further resection. None has any objective or subjective functional deficit. The complaints were cosmetic.

In my hands, this operation has been an eminently satisfactory answer to all the above problems. Many times it has been performed in conjunction with other surgical procedures on the feet. No cosmetic defect is produced (Fig. 2). It seems certain that the patient has no idea of what or how much has been removed from his foot; nor, insofar as function is concerned, does he realize that anything has been removed, even though he is informed routinely. He seems to dismiss it postoperatively as of no importance.

Following this procedure, the fifth toe usually retracts proximally about 1/4 to 3/8 inch. This retraction makes it easier to fit the foot with a shoe. There have been no complications.

FIG. 2. Before and after bilateral bunionectomy and resection of the fifth metatarsal heads.

33

A Simple and Satisfactory Method of Strapping the Lumbosacral Region of the Back*

JOHN T. BATE, M.D.†

The method that I am about to describe is so simple that I have hesitated to draw attention to it, but I am emboldened by the satisfactory results that have been achieved with patients whom it has been difficult to relieve and to satisfy in the past.

One morning I bent forward with my knees straight in order to remove something from a traveling bag. As I started to regain the erect position I felt a catch in the lower part of the back. This was not severe at first, but within a few hours the pain became so severe that it was necessary for me to refer some surgical patients to others. I found that, leaning backward would cause muscle spasm and pain so severe in extent that it was necessary to hold to some object in order to stand. A lumbosacral support and bed rest gave some benefit, but it was not until a Williams low-back brace was fitted that I was relieved sufficiently to continue my work. It seemed obvious to me that the most beneficial part of this brace was that it prevented hyperextension or an increase in lordosis at the lumbosacral region.

In trying to apply this thought to relief of the acutely painful low-back conditions seen in my office, it was evident that I could not order a 50-dollar Williams low-back brace at once for each patient but that perhaps the same effect could be obtained on a temporary basis by splinting the lumbar lumbosacral region.

Having in my office some wooden splints of the type that was used formerly in the treatment of fractures of the bones of the forearm, made of a soft type of wood firmer than the yucca or the basswood splint, I sawed one of these in half. This half measured 9 inches long, 4 inches wide and 3/16 inch thick. To each end a piece of sponge rubber ½ x 4 x 5 inches was attached by means of adhesive tape so that it projected over the ends and the sides of the splint. The splint and the sponge rubber next were covered with two strips of Red Cross type folded gauze long enough to overlap the ends of the splint 2 or 3 inches and the sides approximately 1 inch. After protecting the skin of the back flanks and the abdomen with compound tincture of benzoin, a piece of Red Cross type gauze was cut, opened up and placed over the abdomen so as to protect the skin and the hair from adhesive. With the splint held in the mid-line of the back, from the proximal segment of the sacrum to the lumbodorsal region, and the patient leaning forward slightly with his hands in front in an effort to maintain a flat lumbar region, the whole was held in place by circularly applying 4-inch elastic adhesive bandage, the ends secured with ordinary

* Read at the meeting of the American Fracture Association held in El Paso, Tex., October, 1957.

† Louisville, Ky

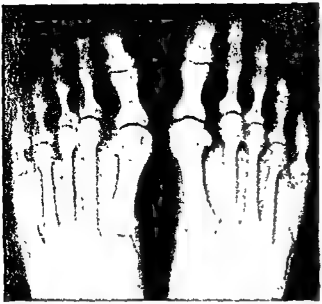


Fig. 1. Roentgenogram showing extent of resection.

metatarsal with removal of all the metatarsal distal to this (Fig. 1). This resection amounts to between one half and two thirds of the distal portion of the metatarsal. I then began to remove the metatarsal without amputation of the toe. In the last 6 years I have performed this operation over 60 times on 38 patients with uniform success. Removal of the head of the metatarsal is accepted much more readily by patients than amputation of the fifth toe. The only cases that have had any subsequent complaint whatever are the early ones, in which surgery was too conservative and the metatarsal was resected distal to the middle. None of these has required further resection. None has any objective or subjective functional deficit. The complaints were cosmetic.

In my hands, this operation has been an eminently satisfactory answer to all the above problems. Many times it has been performed in conjunction with other surgical procedures on the feet. No cosmetic defect is produced (Fig. 2). It seems certain that the patient has no idea of what or how much has been removed from his foot; nor, insofar as function is concerned, does he realize that anything has been removed, even though he is informed routinely. He seems to dismiss it postoperatively as of no importance.

Following this procedure, the fifth toe usually retracts proximally about ¼ to ⅜ inch. This retraction makes it easier to fit the foot with a shoe. There have been no complications.

Fig. 2. Before and after bilateral bunionectomy and resection of the fifth metatarsal heads

33

A Simple and Satisfactory Method of Strapping the Lumbosacral Region of the Back*

JOHN T. BATE, M.D.†

The method that I am about to describe is so simple that I have hesitated to draw attention to it, but I am emboldened by the satisfactory results that have been achieved with patients whom it has been difficult to relieve and to satisfy in the past.

One morning I bent forward with my knees straight in order to remove something from a traveling bag. As I started to regain the erect position I felt a catch in the lower part of the back. This was not severe at first, but within a few hours the pain became so severe that it was necessary for me to refer some surgical patients to others. I found that, leaning backward would cause muscle spasm and pain so severe in extent that it was necessary to hold to some object in order to stand. A lumbosacral support and bed rest gave some benefit, but it was not until a Williams low-back brace was fitted that I was relieved sufficiently to continue my work. It seemed obvious to me that the most beneficial part of this brace was that it prevented hyperextension or an increase in lordosis at the lumbosacral region.

In trying to apply this thought to relief of the acutely painful low-back conditions seen in my office, it was evident that I could not order a 50-dollar Williams low-back brace at once for each patient but that perhaps the same effect could be obtained on a temporary basis by splinting the lumbar lumbosacral region.

Having in my office some wooden splints of the type that was used formerly in the treatment of fractures of the bones of the forearm, made of a soft type of wood firmer than the yucca or the basswood splint, I sawed one of these in half. This half measured 9 inches long, 4 inches wide and 3/16 inch thick. To each end a piece of sponge rubber ½ x 4 x 5 inches was attached by means of adhesive tape so that it projected over the ends and the sides of the splint. The splint and the sponge rubber next were covered with two strips of Red Cross type folded gauze long enough to overlap the ends of the splint 2 or 3 inches and the sides approximately 1 inch. After protecting the skin of the back flanks and the abdomen with compound tincture of benzoin, a piece of Red Cross type gauze was cut, opened up and placed over the abdomen so as to protect the skin and the hair from adhesive. With the splint held in the mid-line of the back, from the proximal segment of the sacrum to the lumbodorsal region, and the patient leaning forward slightly with his hands in front in an effort to maintain a flat lumbar region, the whole was held in place by circularly applying 4-inch elastic adhesive bandage, the ends secured with ordinary

* Read at the meeting of the American Fracture Association held in El Paso, Tex., October, 1957.

† Louisville, Ky.

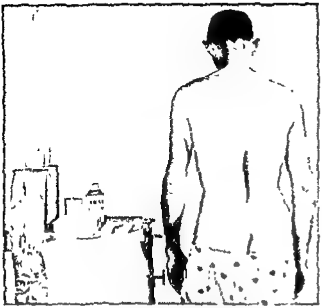


FIG. 1. Patient with acute lumbosacral back discomfort Supplies used in strapping.

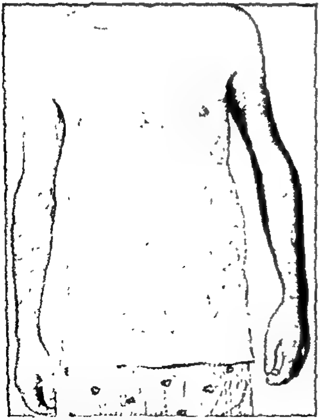


FIG. 2. Some gauze unfolded so as to protect the hair of the abdomen It is held in place by the compound tincture of benzoin spray that has been applied to the skin.

FIG. 3. The 11-inch wooden back splint has been padded at each end with sponge rubber held in place with 2-inch adhesive. Some folded sterile gauze is being cut sufficiently long to fold over each end and protect the skin from the sponge rubber.

2-inch adhesive and the protruding gauze fastened down by means of the same type of adhesive. During the summer months it was found to be advantageous to protect the skin by means of a 3-inch gauze roller bandage applied circularly and then putting the elastic adhesive over this. Because of the variation in height of individuals, splints 10, 11 and 12 inches long were kept in stock As it was impossible to obtain a new supply of the wooden forearm splints, additional ones were made up by a planing mill.

FIG. 4. During hot weather a 3-inch gauze roll of bandage is used to protect the skin from the elastic adhesive and hold the splint in place.

FIG. 5. The 4-inch elastic adhesive bandage is being applied so as to turn the gauze edges under.

I estimate the cost of the material used in one of these strappings to be about $1.45.

I had hoped to keep a cross index of all back cases seen during the period of approximately 6 months covered by this report, but records were kept only of the people who were strapped by this method. There were 107 cases. Twenty-six (24.3%) were characterized as excellent results, immediate relief having been obtained and discomfort having disappeared when the strapping was removed approximately 4 days later. Fifty-three (49.5%) obtained very good results, indicating that they were 95 per cent better after wearing the strapping for from 2 to 4 days. The remarks heard were as follows: "That harness sure fixed me up fine." "That board certainly hoped me." "Had great relief right away." Twelve (11.2%) showed fair to good results. They all felt that they had been relieved definitely but required some additional treatment, such as a Williams low-

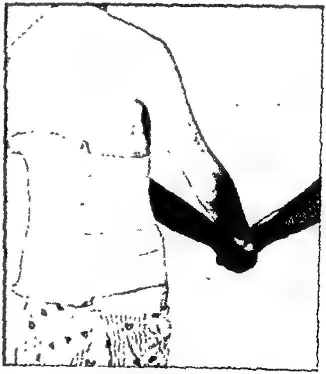


FIG. 6. The completed support. This man left the office and walked 3 blocks to his place of employment following this strapping. When it was removed 4 days later, he thought that he was completely relieved.

back brace or a lumbosacral or a sacro-iliac support. Six (6.5%) were classified as poor results. They felt that they had not been benefited. Hospitalization or hospitalization and traction, physiotherapy, consultation and additional support were used. One of these left me and took chiropractic treatments. In the whole group 4 were hospitalized, 6 were provided with the Williams low-back brace, 4 with lumbosacral supports, and 2 with the Williams low-back brace and physiotherapy. Two of those being given lumbosacral supports had sufficiently marked dermatitis under the adhesive to prevent further strapping.

From my experience to date I conclude that this method is very useful in the individual who has an acute low-back pain of from a few hours' to 24 hours' duration. It has no value in subacute and chronic low-back pain; nor does it benefit neurotic or introspective individuals, especially if they have already been told that they have a slipped disk or know somebody who had one.

All were instructed in proper posture, in methods of stooping, lifting, sitting and exercising, and in the preparation of a stiff bed. Some were given Empiral tablets or aspirin and soda.

34

A Sterilizable Container for Special Instruments and Internal Fixation Apparatus for Operating-Room Orthopaedic Surgery Procedures*

WILLIAM COMPERE BASOM, M.D.

This container will hold all the internal fixation apparatus that may be needed for various surgical procedures. A full set of screws always is present. It is easy for the nurse to check when the supply is becoming low.

A full set of Smith-Petersen nails, trochanteric anchor plates, bone plates with slotted holes, tibial bolts and wire can also be placed in this type of box. When the apparatus is needed, the nurse can remove

* This plate and internal fixation apparatus container is at present in use in the operating rooms at Hotel Dieu Sisters' Hospital and at Providence Memorial Hospital, El Paso, Tex., by the El Paso Orthopaedic Surgery Group, Doctors Breck, Basom, Leonard, Palafox and Kosicki.

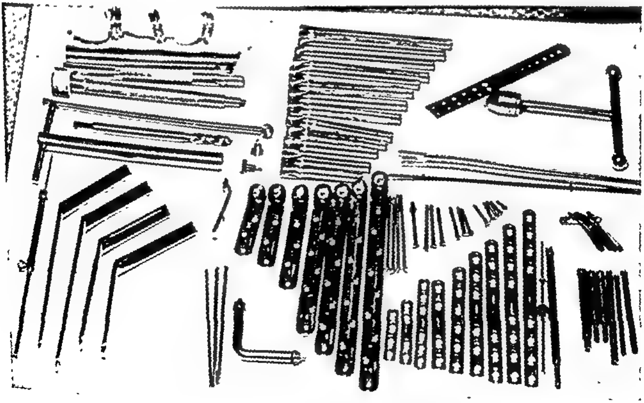


FIG 1. Showing contents of box arranged for display.

it easily from the box and line the items up on the table prior to the operation, when the surgeon can check them quickly.

Special instruments also can be included, such as driver, impactor, starter, hand chuck, T wrench, depth gauge, drill points. In fact, most of the items that may be needed are always present and available.

Boxes like this have been used by us for a period of 14 years. We feel that they are a definite help to the orthopaedic surgeon. Further, we feel that this new model is superior to the ones reported previously. The previous boxes were made by a brace shop. This one is the first that we have been able to have manufactured commercially.* Its construction and design, we feel, are superior.

CONCLUSION

A commercially manufactured sterilizable container for the operating room has been placed on the market. The design and the construction are superior to the sterilizable containers for special instruments and internal fixation apparatus for the operating-room surgery procedures that we have utilized previously.

* Mr. Frank O. Wright, 739 Jackson Avenue, Memphis, Tenn.

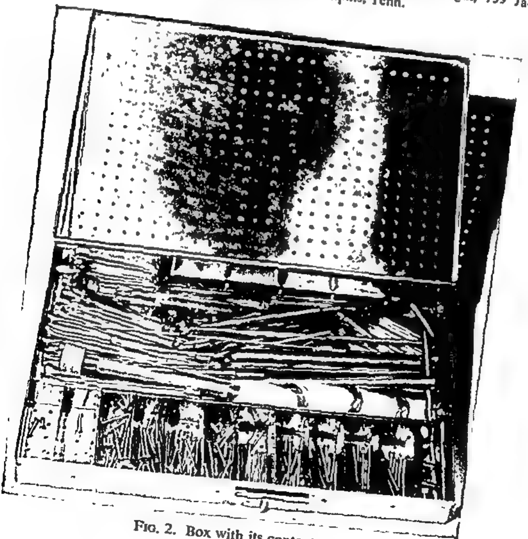


FIG. 2. Box with its contents.

Index

Cumulative Index (Nos. 7-12)